TECHNICAL REPORT TR 78-10-72

APPLICATIONS OF DECISION ANALYSIS TO THE U.S. ARMY AFFORDABILITY STUDY

DECISIONS AND DESIGNS INCORPORATED

Dennis M. Buede
Michael L. Donnell
Phillip H. Feuerwerger
Janice E. Ragland

December 1978

ADVANCED DECISION TECHNOLOGY PROGRAM

CYBERNETICS TECHNOLOGY OFFICE
DEFENSE ADVANCED RESEARCH PROJECTS AGENCY
Office of Naval Research • Engineering Psychology Programs

The objective of the Advanced Decision Technology Program is to develop and transfer to users in the Department of Defense advanced management technologies for decision making. These technologies are based upon research in the areas of decision analysis, the behavioral sciences and interactive computer graphics. The program is sponsored by the Cybernetics Technology Office of the Defense Advanced Research Projects Agency and technical progress is monitored by the Office of Naval Research – Engineering Psychology Programs. Participants in the program are:

Decisions and Designs, Incorporated
Harvard University
Perceptronics, Incorporated
Stanford Research Institute
Stanford University
The University of Southern California

Inquiries and comments with regard to this report should be addressed to:

Dr. Martin A. Tolcott
Director, Engineering Psychology Programs
Office of Naval Research
800 North Quincy Street
Arlington, Virginia 22217

or

Dr. Stephen J. Andriole
Cybernetics Technology Office
Defense Advanced Research Projects Agency
1400 Wilson Boulevard
Arlington, Virginia 22209

TECHNICAL REPORT TR 78-10-72

APPLICATIONS OF DECISION ANALYSIS TO THE U.S. ARMY AFFORDABILITY STUDY

by

Dennis M. Buede, Michael L. Donnell, Phillip H. Feuerwerger, and Janice E. Ragland

Sponsored by

Defense Advanced Research Projects Agency
ARPA Order 3469

December 1978

DECISIONS and DESIGNS, INC.
Suite 600, 8400 Westpark Drive
P.O.Box 907
McLean, Virginia 22101
(703) 821-2828

ABSTRACT

This report describes two applications of decision analysis in support of the Army's Affordability Study and Army Program development. The purpose of these applications is to assist decision makers to prioritize programs competing for scarce resources.

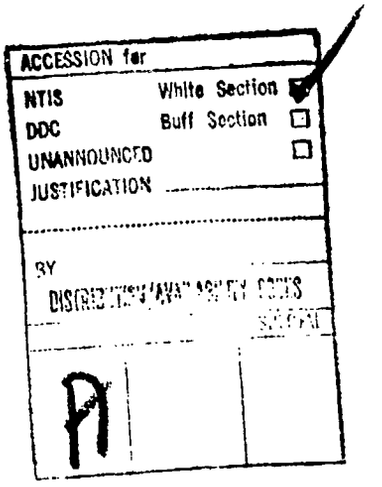
The first application of decision analysis is the use of cost-benefit analysis to rank individual programs of the Army's FY 80-84 Program Objectives Memorandum (POM). The process involves quantifying the relative benefits of each program according to an Army mission value system. The benefits are judgmental assessments, obtained by first having each sponsor (e.g., operations, personnel) quantify the relative benefits of programs within his area. An "honest broker" group then determines the relative benefits of randomly selected programs from each sponsor's list and uses this information to merge the programs into a single list. Once the benefits have been quantified and divided by program costs, the programs are prioritized on the basis of cost-benefit (benefit per dollar).

The second application of decision analysis uses multi-attribute utility analysis in support of Training and Doctrine Command's (TRADOC) Battlefield Development Plan (BDP). The key functional areas comprising a future division's fighting capability are evaluated by using a hierarchy of criteria to determine shortfalls. The resulting deficiencies, ranked according to severity, provide the basis for corrective actions.

These applications show that military judgment concerning the value of disparate programs can be elicited and quantified and are adaptable by existing decision forums. Moreover,

the effort to establish criteria, document how individual programs meet the criteria, and openly discuss the relative merits of programs led to a much greater understanding of the issues. This improved understanding, in turn, enhanced the ability to communicate to OSD Army requirements and values in program and budget terms.

It is recommended that the Army continue to use decision analysis in support of POM/Budget development. Multi-attribute utility analysis should be used at Department of Army (DA) to develop an Army hierarchy of specific criteria on which to base mission benefit values.



SUMMARY

This report describes several applications of decision analysis to the Army's Affordability Study. These applications are focused on the allocation of resources to support the requirements, concepts, plans, and programs of the Army. As part of the Program Objectives Memorandum (POM) preparation, the Army must develop a priority ranking of its functional programs within the fiscal constraint window provided by the Office of the Secretary of Defense (OSD). This constitutes an analysis around the margin (that is, within the neighborhood) of the final constraints that will be imposed to determine how the Army will spend its money. Since the Army's needs always exceed the capability permitted by the fiscal constraints, this marginal analysis should be based upon the relative cost-benefit of the functional programs in order to ensure that the Army derives as much benefit as possible within the limits of these constraints. Initially, these priorities should be based solely upon the relative benefit to the Army of these functional programs. Then, the priorities can be modified to reflect the many economic and political influences that are important to society as a whole.

Decision analysis is a quantitative procedure for the systematic evaluation of the alternatives available to a decision maker. Decision-analytic techniques are used to structure a decision problem into clearly defined components, so that all options, outcomes, values, and probabilities are depicted. The explicit representation of the decision not only provides a recommended course of action, but also facilitates communication among those involved. So, it should be emphasized that decision analysis does not replace decision makers but structures the role of wise human judgment in the decision process.

The first application of decision analysis described in this report is the use of cost-benefit analysis to rank the Army Program Development Increment Packages (PDIP's) and Program Analysis Resource Review (PARR) issues. The cost-benefit process involves quantifying the relative benefits and costs of each program. Since the purpose of the prioritization is to determine the allocation of money to a discrete number of programs, the quantification of benefit is done according to an Army mission value system, not according to a monetary value system.

The benefits are judgmental assessments, obtained by first quantifying the relative benefits of programs within the areas of each sponsor (e.g., operations, personnel) and then determining the relative benefits of selected programs from each sponsor's list. Once the benefits have been quantified, the programs can be prioritized from the most cost-beneficial (benefit per dollar) to least cost-beneficial. This procedure has been applied to the prioritization of 334 PARR issues and 185 PDIP's in the POM FY 80-84 development. The benefits of the PDIP's were updated during the budget preparation in August and September. This cost-benefit analysis was tested within the current Army staff organization and was found to be a highly disciplined staff action using the relevant expertise of each staff element. The decision-analytic process provided a very useful starting point from which decision issues could be determined and discussed by the decision makers. Therefore, it is recommended that these procedures be codified and adopted as the Army prioritization system.

Multi-attribute utility analysis is the second decision-analytic technique investigated during this affordability study. A multi-attribute utility model is hierarchical

in nature, as the top-level factor in the analysis is successively divided until highly specific characteristics or parameters are detailed at the bottom of the hierarchy. Multi-attribute utility analysis can be used in the relative evaluation of mission capabilities to develop a framework that sponsors could use to scale the benefits of their programs. It could also be used to develop a Support Packaging Methodology to be used in conjunction with the Army's Force Packaging Methodology. These two methodologies would be most useful in establishing levels of functional programs to be ranked in the marginal analysis during the POM preparation.

CONTENTS

FIGURES

TABLES

ABBREVIATIONS

AAD	Army Automation Directorate
APDM	Amended Program Decision Memorandum
ASARC	Army Systems Acquisition Review Council
BDP	Battlefield Development Plan
BRC	Budget Review Committee
CM	Countermeasure
COBE	Command Operating Budget Estimate
CONUS	Continental United States
CRRC	Construction Requirements Review Committee
DA	Department of the Army
DAB	Director of the Army Budget
DCSLOG	Deputy Chief of Staff for Logistics
DCSOPS	Deputy Chief of Staff for Operations
DCSPER	Deputy Chief of Staff for Personnel
DCSRDA	Deputy Chief of Staff for Research, Development, and Acquisition
EUR-KOR	European and Korean
FEBA	Forward Edge of the Battle Area
FY	Fiscal Year
FYDP	Five Year Defense Plan
MAA	Mission Area Analysis
MACOM	Major Command
MAUA	Multi-Attribute Utility Analysis
NATO	North Atlantic Treaty Organization
NGB	National Guard Bureau
OCAR	Office of the Chief of Army Reserve

ABBREVIATIONS (Con't)

OCE	Office of the Chief of Engineers
OSD	Office of the Secretary of Defense
OTSG	Office of the Surgeon General
PAE	Program Analysis and Evaluation Directorate
PA&ED	Program Analysis and Evaluation Directorate
PARR	Program Analysis Resource Review
PDIP	Program Development Increment Package
PDM	Program Decision Memorandum
PGRC	Program Guidance Review Committee
PIN	Program Issue Narrative
POM	Program Objectives Memorandum
RDAC	Research, Development, and Acquisition Committee
SIPC	Stationing and Installations Planning Committee
TRADOC	Training and Doctrine Command
Wx	Weather

1.0 INTRODUCTION

This report describes several applications of decision analysis to the U.S. Army's Affordability Study, conducted by the Program Analysis and Evaluation Directorate (PA&ED), Office of the Chief of Staff Army. The Affordability Study has been prompted by the recognition that in the current technological explosion, opportunities exceed resources to exploit. The central question is: How do we modernize, maintain readiness, enhance sustainability, develop human commitment, and so forth, to meet the threat of the 1990's, given 3% real growth? That is, the U.S. Army must maintain and program the most effective fighting force for the future within very clear-cut budgetary constraints. To do this, the relative merits of all Army programs must be compared. The Army is developing the tools and disciplines needed to evaluate the marginal mission benefit of individual programs and thereby develop a means of prioritizing competing issues.

The Army's Affordability Review Program is designed to offer decision makers a rational means of responding to these new management challenges. The Army uses the term "affordability" to describe efforts within the Army Staff to measure and evaluate marginal costs and mission benefit. The efforts stem from the realization that an initiative, though highly desirable, may not be affordable. An affordability analysis, then, is an investigation of the effects of constrained resources on alternative Army programs. The objective of such analysis is to maximize combat capabilities within a projected level of resources. Until now, affordability decisions were made almost intuitively, given the absence of a systematic and disciplined effort to assess the full impact of a program on the planning, programming, and budgetary continuum. The applications of decision analysis described in this report are part of the affordability analyses.

The primary problem addressed by these decision-analytic applications is the current lack of a defined basis (methodology with analytic rigor) to assist decision makers in determining the proper allocation of constrained dollar resources among competing Army programs. Therefore, the purpose here is to provide the Army an explicit and documented basis for allocating constrained resources among competing requirements, concepts, and plans. To accomplish this, there are three objectives:

1. determine whether decision analysis can be applied in a rigorous way to the Army's existing resource allocation process;

2. develop an Army procedure for prioritizing decision units across appropriations;

3. evaluate the utility of the technique for prioritizing the allocation of resources among alternative requirements, plans, concepts, strategies, and programs given fiscal, manpower, and time resource constraints.

In order to be successful, any prioritization procedure must include:

- uniform rationale for identifying program packages;
- values based on the mission goals;
- functional (multi-appropriation) program packages;
- a funding strategy for various fiscal constraints; and
- documentation of the process.

The rationale for defining program packages to be considered for funding should be open and common to all program sponsors (proponents). The relative values for these packages should be based on Army mission considerations, with nonmission factors considered as a deviation from the prioritization. The proponents, and therefore the program packages, should be based on functional, not appropriation, categories. The prioritization process should result in a funding strategy for a number of fiscal constraints that might be imposed by the Office of the Secretary of Defense (OSD). Finally, the process should be documented and reproducible.

Section 2.0 describes the decision-analytic methodologies used in these applications. The first methodology addresses the prioritization of decision units directly by quantifying their relative benefits and by using the cost-benefit criterion to prioritize. Multi-attribute utility theory, the second methodology, is used to analyze the relative capabilities of the Army within missions. This analysis of capabilities is an indirect link to the prioritization problem because it provides a very useful framework for quantifying the relative benefits of the decision units in the first application.

Section 3.0 discusses the application of cost-benefit methodology to the prioritization of the Program Analysis Resource Review (PARR), the Fiscal Year (FY) 80-84 Program Objectives Memorandum (POM-80), the Program Development Increment Packages (PDIP's), and the decision packages of the FY 80 budget. Section 4.0 discusses the application of multi-attribute utility theory to the analysis of Army's mission capabilities. Section 5.0 contains a brief treatment of topics related to these two applications. Finally, the conclusions and recommendations are presented in Section 6.0.

2.0 METHODOLOGY--DECISION ANALYSIS

Decision analysis is a quantitative method for the systematic evaluation of the costs or benefits accruing to courses of action that might be taken in a decision problem. It entails identification of the alternative choices involved, the assignment of values (costs/benefits) for possible outcomes, and the expression of the probability of those outcomes being realized. With this information at hand, one can then systematically combine the values and probabilities to show the probable gain or loss associated with each alternative choice. Since 1970, there has been a dramatic burgeoning of efforts by defense agencies to adapt this technology to their day-to-day decision making. Many have found it a way to make better, more defensible decisions.

2.1 The Role of Decision Analysis

In the application of decision analysis, a problem is decomposed into clearly defined components in which all options, outcomes, values, and probabilities are depicted. Quantification takes place in the form of a value or cost for each possible outcome. The probability of these values or costs being realized is stated in terms of objective information or in the form of quantitative expressions of the subjective judgments of experts. In the latter case, the quantitative expression serves to make explicit those subjective qualities which would otherwise be weighted in the decision process in a more elusive, intuitive way.

Beyond its primary role of serving as a method for the logical solution of complex decision problems, decision analysis has additional advantages as well. The formal structure of decision analysis makes clear all the elements in a decision problem, their relationships, and their associated

weights. If only because a decision analysis model is explicit, it can serve an important role in facilitating communication among those involved in the decision process. With a problem structured in a decision-analytic framework, it is an easy matter to identify the location, extent, and importance of any areas of disagreement, and to determine whether such disagreements have any material impact on the indicated decision. In addition, should there be any change in the circumstances bearing upon a given decision problem, it is fairly straightforward to reenter the existing problem structure to change values or to add or remove problem dimensions as required.

It should be emphasized that in no sense does decision analysis replace decision makers with arithmetic or change the role of wise human judgment in decision making. Rather, it provides an orderly and more easily understood structure that helps to aggregate the wisdom of experts on the many topics that may be needed to make a decision. Decision analysis also supports the skilled decision maker by providing him with logically sound techniques to support, supplement, and ensure the internal consistency of his judgments.

In fact, a decision analyst's objective is to facilitate the decision process by structuring the problem with the decision maker and eliciting his or her values and probabilities. Thus, the decision analyst is not a surrogate decision maker putting together a study that is presented to the real decision maker upon completion. Rather, the decision analyst works intimately with the decision-making body to provide a structure they can use to reach the preferred decision.

2.2 Cost-Benefit Analysis for Prioritization

Cost-benefit analysis traditionally has two distinct purposes. The first is to determine the appropriateness of

undertaking a specific action, such as building a dam or a new plant, by determining whether benefits outweigh costs and negative side effects. The second purpose is to achieve the most cost-beneficial allocation of a fixed level of resources among a large number of programs. Basically, the relative benefits of each program must be quantified and reliable cost estimates obtained. For this type of allocation, such relative benefits are quantified according to a mission-oriented value system, not a monetary (dollar) value system.

2.2.1 The elicitation procedure - Subjective benefit assessments can be made for very diverse programs by an elicitation procedure that motivates the manager of a set of programs to provide his true subjective estimates. This elicitation procedure begins with the quantification of benefits for sets of similar programs, each set having the same expert manager or sponsor. Psychologists and decision analysts have observed that the best way to obtain reliable quantifications of this sort is to use paired comparisons, that is, to ask the expert to make choices between two packages until points of indifference can be found. Once the resulting benefit scales have been assessed, each manager is asked to provide rationale for the benefit numbers attached to his programs.

The following example is a useful illustration of this procedure. A sponsor proposes ten ordinally ranked programs designated A through J. These are listed in Table 2-1, along with an initial benefit scale, total cost, and initial benefit/cost ratio. The decision unit with the largest benefit/cost ratio is selected, and the remaining units are prioritized according to the cost-benefit criterion, which guarantees that for any budget constraint, the most benefit will be obtained:

J, I, D, A, F, E, B, H, G, C.

PROCUREMENTS	INITIAL BENEFITS	TOTAL COSTS	BENEFIT COST
A	100	16	6.2
B	99	36	2.8
C	95	56	1.7
D	90	9	10.0
E	87	30	2.9
F	83	20	4.2
G	70	35	2.0
H	70	26	2.7
I	60	2	30.0
J	55	1	55.0

Table 2-1

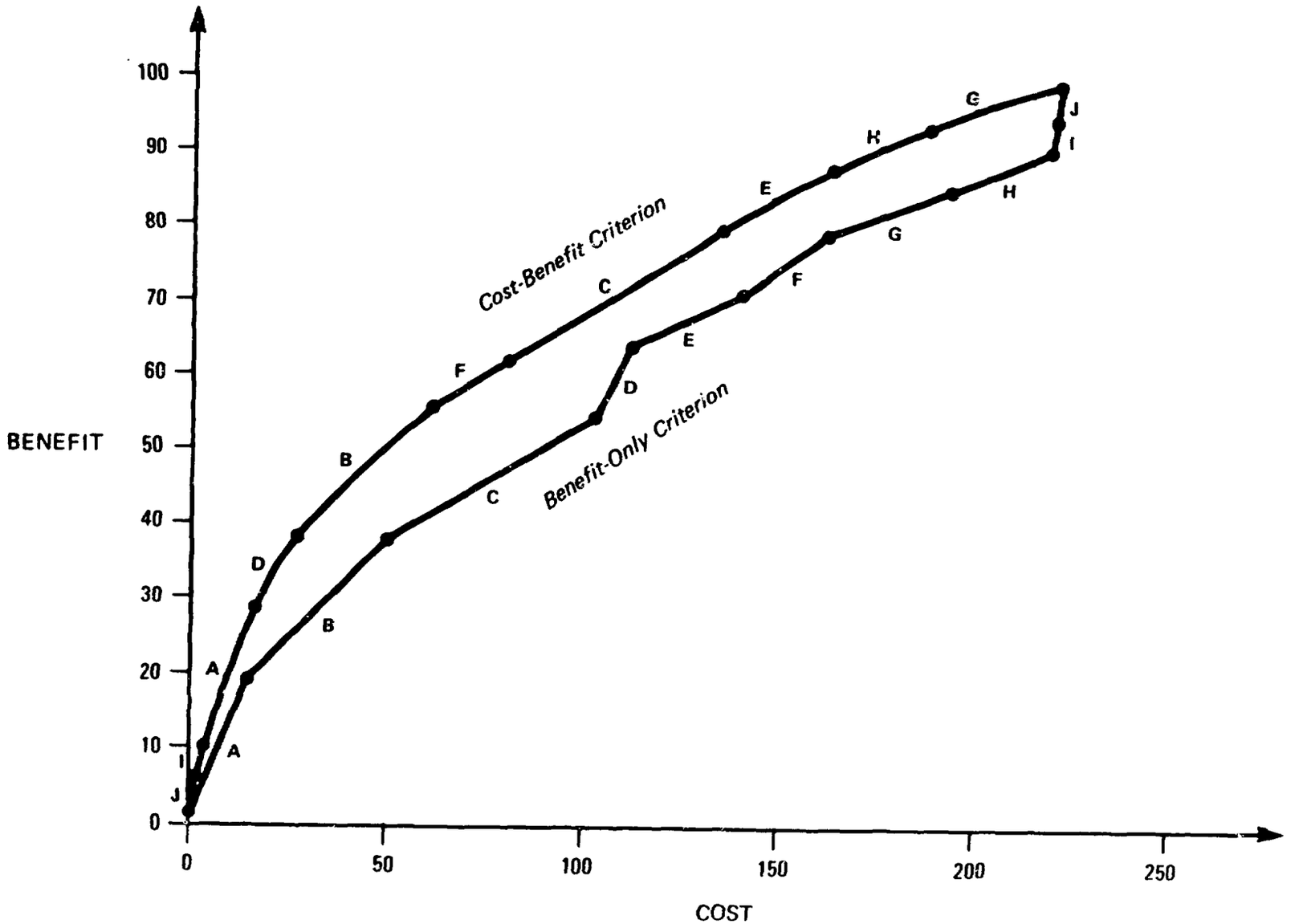
PROCUREMENTS – INITIAL COMPARISONS

Figure 2-1 illustrates the difference in benefit between the cost-benefit and benefit-only criteria for all levels of cost. The two curves depict the accumulation of benefit and cost as the decision units are purchased using cost-benefit and benefit-only criteria. At this point, the initial benefit numbers have not been spread out sufficiently to properly order them; further iterations will produce a proper ordering. Thus, using the cost-benefit criterion with these benefit numbers is almost equivalent to ordering the decision units by cost in descending order.

The second iteration of this process begins by comparing decision units J, I, and D with A. The package J, I, D costs nearly as much as A but should be twice as beneficial as A. However, when asked which he preferred, the sponsor said A had more benefit than J, I, D. So A's benefit was adjusted to 250 to reflect the strength of his preference.

Next, note that A and B are nearly equivalent to the package J, I, D, A, F in cost. Since A is common to both packages, and there are no interdependencies between the procurements, B can be compared to J, I, D, F. In this case, J, I, D, F were strongly preferred, and the sponsor felt B was equivalent to J, I, D. So B's benefit was raised to 215. In this way, paired comparisons are used to reach a level of indifference.

Through this process, the sponsor develops a concept of a true zero benefit and then scales the relative benefits of his programs between zero and one hundred (assigned to the most beneficial program). The resultant ratio-benefit scale reflects the sponsor's value system. The paired-comparisons procedure was repeated until the sponsor was satisfied that the benefit numbers reflected his judgment. The normalized scale is presented in Table 2-2. The final order of cost-benefit


BENEFIT
COST
Cost-Benefit Criterion
Benefit-Only Criterion
0
10
20
30
40
50
60
70
80
90
100
0
50
100
150
200
250
A
B
C
D
E
F
G
H
I
J
K

PROCUREMENTS	COSTS ($)	ORIGINAL BENEFITS	FINAL (NORMALIZED) BENEFITS	BENEFIT / COST
A	16	100	100	6.2
B	36	99	83	2.3
C	56	95	80	1.4
G	35	70	72	2.1
D	9	90	58	6.4
E	30	87	37	1.2
F	20	83	30	1.5
H	26	70	19	0.7
I	2	60	15	7.5
J	1	55	8	8.0

Table 2-2

PROCUREMENTS – FINAL COMPARISONS

buys is:

J, I, D, A, B, G, F, C, E, H.

Figure 2-2 shows the final differences between buying with the cost-benefit criterion versus the benefit-only criterion. For a fiscal constraint of $100, the cost-benefit criterion provides 68% of the possible benefit, a 33% increase over the benefit-only criterion. Clearly, to use the cost-benefit criterion effectively and to be considered fiscally responsible, sponsors must spend considerable time producing a good set of benefit numbers that reflect the spread they believe actually exists between their programs.

Because the thought required to arrive at the final benefit scale requires more than that typically used to derive a simple priority list, the process described here is of great help in facilitating judgments and developing supporting rationale.

2.2.2 Cross-sponsor benefit assessments - After the benefit scales and supporting rationale have been assessed for each sponsor, a group comprised of the appropriate experts is formed to provide an overall benefit scale covering the diverse decision units listed by all the sponsors. This cross-sponsor group must have a clear picture of the potential benefit (in terms of the Army's effectiveness) of the decision units. Their job is to provide a benefit scale for a small, selected subset of all the decision units. The subset includes one item from each of the sponsor's lists, and the benefit scale provides the information necessary to collapse all the individual sponsor benefit scales onto one scale. It is this cross-sponsor elicitation of benefits that motivates each sponsor to provide his true benefit estimates, as discussed in the next paragraph.

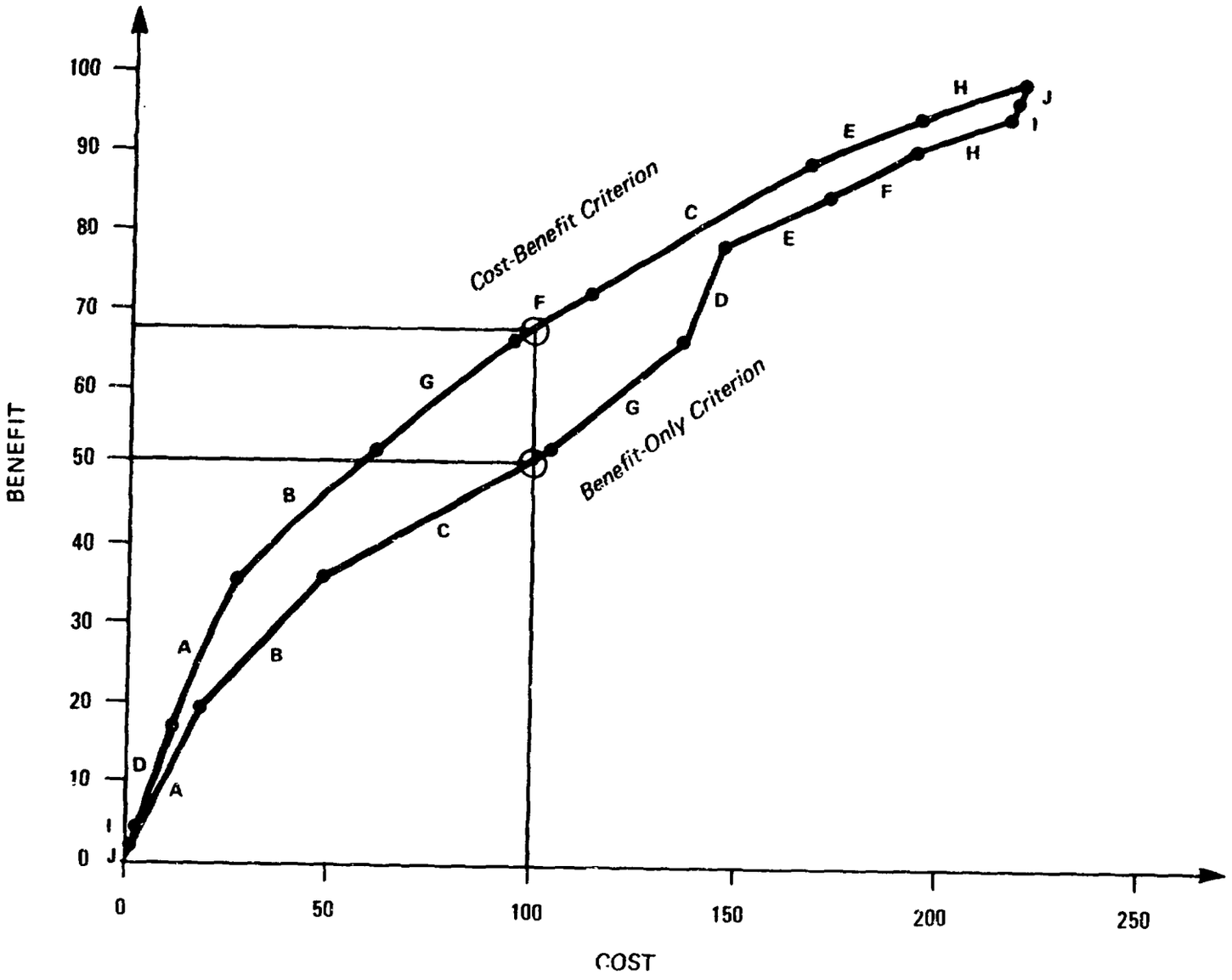


Figure 2-2

COST-BENEFIT VS. BENEFIT-ONLY CRITERIA: FINAL COMPARISONS

After the final benefit scale is determined, this group must provide supporting rationale. Both the rationale and the numerical benefit scales provide the basis for the cost-benefit analysis and justification.

As an illustration of the cross-sponsor benefit scaling, consider the following two-sponsor example. Each sponsor, 1 and 2, has four decision units and has assigned benefits as shown in Figure 2-3. The cross-sponsor group is asked to compare B and O and decides that O is twice as beneficial as B. (Typically, there are eight to ten sponsors, and the iterative benefit assessment procedure described above for each sponsor is used.) This comparison between B and O provides enough information to rescale all of sponsor 1's decision units onto sponsor 2's scale. Since B must be 15 on sponsor 2's scale, the 60 on sponsor 1's scale is divided by four, as are the values of A, C, and D. This is shown on Figure 2-4. If a sponsor contracts his benefit scale more than his true preferences would dictate, his programs may do poorly in the final analysis. For example, if sponsor 1 had claimed B's benefit was 90 rather than 60, his entire scale would have to be divided by 6 rather than 4 to be consistent with the belief that B is half as beneficial as O.

Cross-sponsor benefit judgments are difficult to make because decision units are often so diverse. For this reason, the cross-sponsor group is asked to develop two or three scales, using different decision units from each sponsor's list each time. This is a way of triangulating on the problem that forces inconsistencies to surface. Finding the reasons for these inconsistencies and resolving them strengthens the final result and makes it more defensible.

Once the final cross-sponsor benefit scale has been chosen, the relative benefits of all the decision units are made explicit. The programs have been ranked in terms of

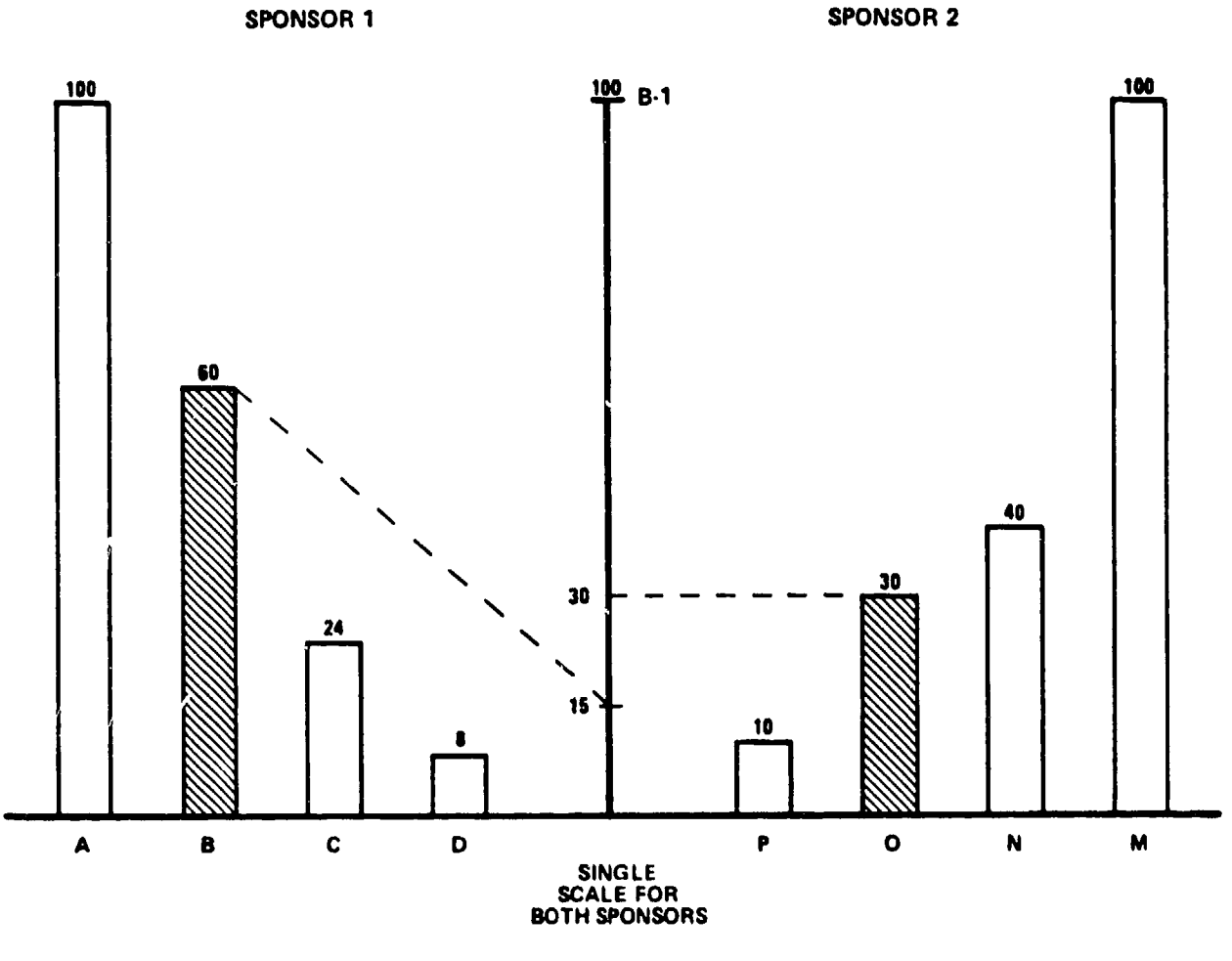


Figure 2-3
CROSS-SPONSOR BENEFIT RANKING

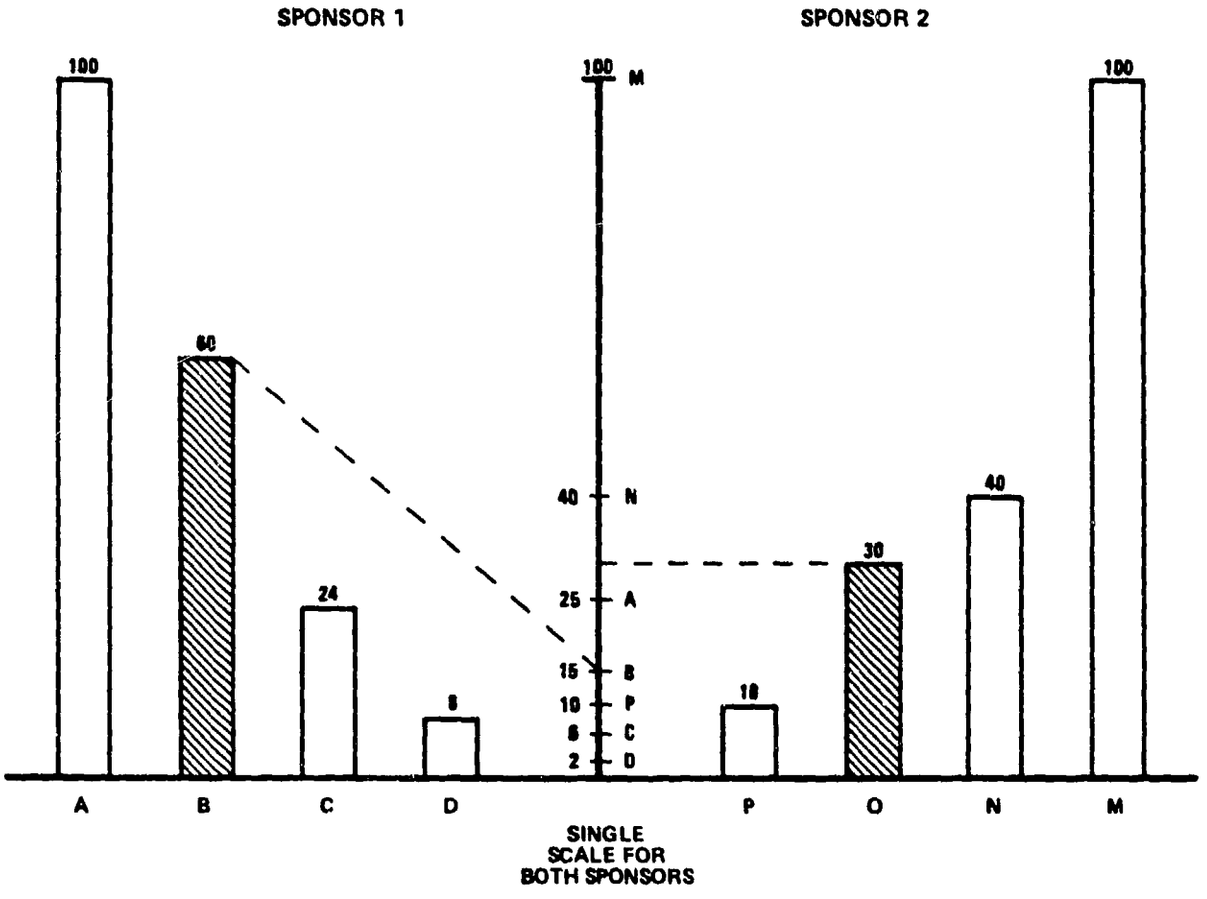


Figure 2-4

TWO-SPONSOR BENEFIT SCALE

benefit on a corporate scale. Now the benefit/cost ratios can be calculated for each decision unit, and the decision units prioritized from most cost-beneficial to least cost-beneficial.

2.3 Multi-Attribute Utility Theory for Mission Capability Analysis

A multi-attribute utility model is hierarchical in nature, starting with the specified top-level factor for which an overall evaluation is desired. This factor is successively decomposed into subfactors in descending levels of the hierarchy such that each successive level is more specific than the one preceding. At the lowest level of the hierarchy are predictable or observable technical (or other) characteristics of the system under evaluation. These lowest level, highly specific characteristics are typically system parameters. A characteristic of this decomposition is that each level provides the proper focus for the expertise of the many participants in the decision-making process.

Multi-attribute utility analysis (MAUA) has been used to assist the U. S. Army and the Air Force in mission capability analysis. Currently, the U. S. Army Training and Doctrine Command (TRADOC) at Fort Monroe is using this methodology as part of the Battlefield Development Plan. It was used by the Air Force and the Army at Langley Air Force Base during the reconnaissance/surveillance mission area analysis (MAA). (MAUA has also been used in numerous system evaluations for the Army and the Navy.)

The hierarchical model for the reconnaissance/surveillance MAA is depicted in Figure 2-5. Performance in the overall mission is first broken into two environmental descriptors, weather and countermeasures (CM). The four environmental categories are day clear with low CM, night

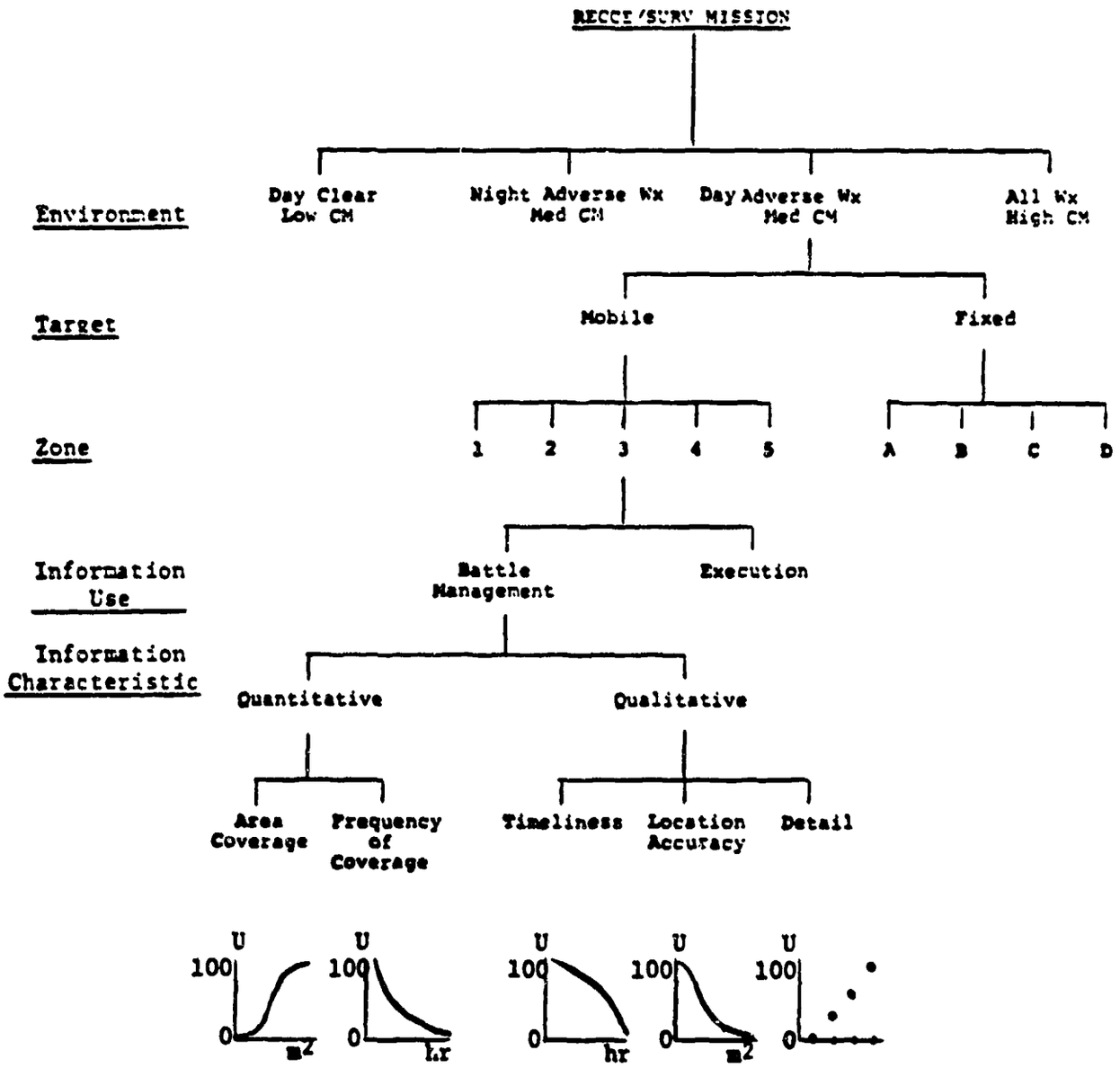


Figure 2-5

MULTI-ATTRIBUTE UTILITY MODEL FOR THE RECONNAISSANCE/SURVEILLANCE MISSION

adverse weather (Wx) with medium CM, day adverse weather with medium CM, and all weather with high CM. The four weather and three countermeasure categories are well defined and measurable.

Next, the targets are classified as either mobile or fixed. Mobile targets include troops, tanks, trucks, and so forth. Runways, command and control posts, and missile sites are examples of fixed targets. For each type of target, zones representing the location of the targets with respect to the forward edge of the battle area (FEBA) are the next level of the hierarchy. The five zones for mobile targets are 0-5 kms back from the FEBA, 5-50 kms, 50-150 kms, 150-350 kms, and 350-1000 kms. The four zones for fixed targets are 0-100 kms, 100-350 kms, 350-700 kms, and 700-1000 kms back from the FEBA.

In the next level of the hierarchy, the military purpose for the information, that is, battle management or the execution of weapons against targets, is specified. The bottom level enumerates the quantitative and qualitative characteristics of the system. The two quantitative capabilities are area coverage and frequency of coverage of the reconnaissance/surveillance systems. Timeliness, location accuracy, and detail are the three qualitative capabilities of individual systems. Each bottom-level characteristic is defined in a measurable way so that utility curves can be defined and elicited.

Value functions were constructed by the appropriate experts for the quantitative and qualitative capabilities for each possible combination of target, zone, and purpose, assuming a 1980 threat. These value functions, scaled between zero and 100, were assumed to be independent of the four weather/countermeasure classifications. The value functions were developed by considering the percentage

effectiveness of all current planning methodologies (battle management) or weapon systems (execution) for each value of a given characteristic, such as location accuracy. Therefore, for a given path through the hierarchy, the zero value for location accuracy is that accuracy that is not sufficient for any weapon system or planning purpose currently in use. At a value of 100 for location accuracy, all weapon systems or planning methodologies would be used to their optimum. The values between zero and 100 were scaled to the appropriate values of location accuracy representing the percentage effectiveness of management or execution. Examples of value functions are shown by the graphs in Figure 2-5.

The importance weights for this hierarchical multi-attribute utility model (Figure 2-5) are driven by the characteristics of the threat. For instance, the importance weights for zones one through five under mobile targets reflect the relative capabilities of the enemy's mobile military equipment in each zone. Likewise, the relative significance of battle management and execution in zone three for mobile targets determines these importance weights--which are also independent of the weather and countermeasure conditions. To assure that the weights were as accurate as possible, experts at different levels of the decision-making process were asked to assign them.

The reconnaissance/surveillance MAA task force used this hierarchical structure to evaluate the current (1980) capability at the bottom levels. Initially, each reconnaissance/surveillance system was evaluated to gain an understanding of the model and the systems. Army, Air Force (both tactical and strategic), European, and national systems were included. Next, for each entry level of the model, a total system capability was defined that reflected such things as the number and types of systems in the

field, their strengths and weaknesses, and the synergisms between them. Judgments were then made concerning the total 1980 reconnaissance/surveillance capabilities in each zone (for mobile and fixed targets) for both 1984 and 1994 threat and attack equipment.

Finally, the total deficiency in the reconnaissance/surveillance mission is defined as the unsatisfied need times the value of the need, summed over all of the MAA model's paths. The unsatisfied need is the difference in value between a perfect set of systems and the current systems. A perfect set of systems would score 100 points on each of the value functions in the model. The value of the needs is a function of the importance weights and is the value of going from a worthless (score of zero) to a perfect system. This numerical MAA model allows the task force to investigate the elements of the mission that have critical deficiencies.

3.0 PRIORITIZATION APPLICATIONS

The cost-benefit methodology (Section 2.1) was used to prioritize both the Program Analysis Resource Review (PARR) issues and the program development increment packages (PDIP's) for POM-80. This section describes the two applications, both of which are based on the theses that:

- Army does have a corporate mission value system;
- the benefit elicitation procedures can establish meaningful benefit relationships.

The Army should have a corporate mission value system for these benefit relationships because it has a corporate view of the threat. The set of attributes considered in assigning an overall benefit value were:

- Army goals;
- Army's force packaging methodology;
- marginal increases in mobility, sustainability, training, standardization, interoperability;
- urgency of need;
- existing levels of threat;
- moral obligations;
- morale; and
- compliance with law.

This set is not exhaustive, and certain attributes were specifically excluded from consideration, such as:

- o OSD-directed program/actions,
- o congressional interest,
- o national or regional economics, and
- o prior commitments.

Basically, the benefit numbers were to reflect the relative contribution of the decision units to the combat effectiveness of the Army. Although political, economic, and other factors do enter the process, they were excluded during the elicitation of benefits. These parameters are considered by the highest level decision makers when they make the final adjustments to the priorities of the PDIP's. (This is discussed further in Section 5.1.) The cost elements are also excluded from the benefit assessment process; they are introduced only after the benefit scale has been produced.

This cost-benefit procedure was determined to be inappropriate during the budget process in August and September because the decision packages were developed in appropriation categories and were not independent of each other. However, the results of the POM analysis were updated based upon the Program Decision Memorandum (PDM) and the Amended Program Decision Memorandum (APDM) of OSD. The budget priorities were matched with POM priorities to ensure that functional programs were not rendered unexecutable by the budget priorities. (This matching of POM and Budget priorities is discussed in detail in Section 3.4.)

3.1 Program Analysis and Resource Review (PARR) Issue Prioritization

3.1.1 Discussion of the PARR prioritization - The overall goal of the PARR prioritization was to rank (in a three-day period) 334 PARR issues by using the previously described cost-benefit methodology. Fifteen Army Staff analysts were the experts who specified the benefit numbers. These analysts were well informed about the PARR issues and familiar with the six Army goal categories listed in Table 3-1. The PARR issues were grouped by both command and functional categories.

Prior to this prioritization, nearly 800 PARR issues underwent a Sieve Analysis during which the following PARR issues were removed from consideration: 1) those funded within basic levels of the major commands (MACOM's); 2) those included in PDIP's; and 3) those not supported by the Staff. The result of this Sieve Analysis was the set of 334 PARR issues to be prioritized.

The first step in the prioritization was to establish a "marker" list of approximately eighty representative PARR issues. Table 3-2 is a classification by functional category and by command, of the eighty-seven items on the marker list settled upon by the participants. For this analysis, the Materiel and Strategic Mobility categories were combined into a single category.

The next step was to evaluate, by command and within categories, the benefits for each of the nineteen cells of the marker matrix. For example, the experts looking at the European and Korean (EUR-KOR) Commands established benefits for its eleven readiness items by assigning a benefit of 100 to the most important single item

1 READINESS

- 11 NATO Initiatives derived exclusively from the NATO mission
- 12 OTHER CONTINGENCIES. Initiatives that support other contingencies as well as the NATO mission
- 13 TRAINING READINESS Programs that relate individual preparedness whether in the training base or in operational units
- 14 UNIT READINESS. Crew and unit training, other initiatives that affect the ability of a unit to perform its doctrinal mission
- 15 MATERIEL READINESS: Programs related to maintaining prescribed operational readiness rates (OR)
- 16 FORCE READINESS. Programs that develop the measures required to implement the readiness goal

2. HUMAN

- 21 RECRUITING: Initiatives to attract and enroll into active and reserve components civilian recruitment
- 22 RETAINING: Initiatives to retain quality people, equal opportunity, quality of life support; recognition; telling the story
- 23 OTHER: Other programs that develop the measures required to implement the human goal

3. MATERIEL:

- 31 NATO: Initiatives designed to improve RSI of NATO forces
- 32 OTHER ALLIES: Initiatives to support national policy in conjunction with other allied forces
- 33 SUPPORT: Initiatives affecting the supply and maintenance system from the field army to Conus, including host nation capabilities
- 34 SUSTAIN: Sustainability programs, to include production base requirements, equipment and consumables
- 35 RESUPPLY: Resupply programs (other than directly to field army) to support all levels with ammunition, fuel, repair parts and subsistence
- 36 OTHER: Programs that develop the measures required to implement the readiness goal

4. STRATEGIC MOBILITY.

- 41 DEPLOYMENT Initiatives related to deployment plans, organization, marshalling, lift, operating procedures and reception plans on arrival at destination
- 42 POMCUS Programs related to acquiring transporting, storing and maintaining POMCUS stocks
- 43 OTHER: Programs that develop the measures required to implement the strategic mobility goal

5. MODERNIZATION/FUTURE DEVELOPMENT

- 51 TECHNOLOGY Programs that exploit new technology to enhance RSI
- 52 TACTICS: Programs that support development/refinement of tactics techniques associated with new equipment
- 53 DOCTRINE Initiatives that relate to doctrinal development with other services and with allies
- 54 EQUIPMENT: Programs that identify requirements for new/improved/modified equipment (includes maintenance, resupply and individual unit training requirements derived from integrated systems approach to developing new equipment and weapons)
- 55 AUTOMATION. Initiatives related to development, acquisition and O&M of information systems for the tactical and support environments
- 56 ORGANIZATION: Initiatives that apply tactical/doctrinal changes to organizational structure
- 57 OTHER: Programs that develop the measures required to implement the future development goal

6. MANAGEMENT:

- 61 BASE OPERATIONS: Programs related to installation resource management, including automation security
- 62 ACTIVE ARMY: Initiatives related to use of and justification of end strength (requirements, force structure, support procedures, host nation support)
- 63 RESERVE COMPONENTS Programs designed to improve the manning, training, equipping, and readiness of reserve components
- 64 CIVILIANS Programs related to use of end strength and initiatives to improve efficiency, such as contracting policies
- 65 SYSTEMS: Initiatives related to systems management of resources
- 66 OTHER Programs that develop the measures required to implement the management goal

Table 3-1

FUNCTIONAL CATEGORIES

"MARKER" PARR ISSUES	Readiness	Human	Materiel	Moderniz'n	M'gmt
EUR-KOR	11	9	5		2
TRADOC-HSC	6	5		6	2
DARCOM	3	2	6		
FORSCOM	8	2	1		4
ACC	7	1		3	4
TOTAL	35	19	12	9	12

Grand Total **87**

Table 3-2

BREAKDOWN OF "MARKER" LIST

and then adjusting the benefits of the other ten readiness items appropriately. In the same manner, the other commands developed benefits for their marker list PARR issues within each functional category.

Next, the marker items from each command were combined into a single list for each functional category. To accomplish this task, the command analysts met and adjusted the benefits of a single highly beneficial item in each command to some mutually agreeable magnitudes. Adjustments were then made for items from the middle of each command's benefit list and finally for items ranking low on each list. After the three adjustments, the items on all the lists were compared to see whether they reflected the beliefs of the analysts. If not, readjustments were made both within and between command lists until a final consensus was achieved. The remaining items in each command's category list were then rescaled to correspond with the new benefits. Each command's portion of PARR's for the designated category was merged with the others to form a single category marker list. The participants reviewed each integrated category marker list and altered the benefits until a level of indifference among combinations of packages was achieved. Any further modification, however, required the consent of the participants. (Modifications and adjustments in subsequent phases of the analysis also required agreement by all participants.)

At this point in the analysis, the five separate marker lists, each corresponding to a different functional category, were combined into an overall marker list. To perform this task, the relative magnitudes of the items with high, medium, and low benefit on each category marker list were adjusted. When the group reached consensual levels of indifference on these adjustments, the remaining items were

combined into the final overall marker list. The participants were given the opportunity to adjust the benefits of any items on the list.

The cost-benefit implications of the benefits assessed for the marker list were then calculated, and the participants adjusted the benefits for these items. For the first time, the real meaning (in a cost-benefit sense) of the benefit assessments surfaced; as a result, some drastic changes in benefit assessments took place. The chief problem uncovered with the first set of benefits was that the range of the benefit scale was much smaller than the range of the cost scale. This resulted in the low-benefit PARR issues appearing to be most cost-beneficial. Since most participants felt this to be inaccurate, the benefit scale was expanded. The result at this point was a scaling of all eighty-seven marker issues. The successive iterations described above had converted an ordinal ranking to a numerical ratio scale of benefits. This benefit scale could now be compared to the cost scale so that a cost-benefit prioritization could be established.

Table 3-3a displays the final listing for the marker issues sorted by benefit; Table 3-3b displays the final listings by cost-benefit. The tables also designate which items could be bought under various budget constraints. The plot of cumulative cost versus cumulative benefit shown in Figure 3-1 is based on Table 3-3. The lower curve in this figure assumes that items are purchased in order of benefit, highest to lowest; the top curve assumes that items are purchased in order of cost-benefit ratio, from lowest to highest. The two plots clearly illustrate the substantial gain in accrued benefit which results when the cost-benefit rather than the benefit-only purchasing strategy is used.

OVERALL ALLOCATION
2 MAR 79

	ITEM		BENEFIT	C/B	COST	CUM COST	
27)	U001	MDC DEF	1400.0	.9	1297	1297	
28)	D094	CENT PROCM	1000.0	31.5	31534	32831	
30)	U095	2 FLOAT DR	850.0	2.9	2954	35785	
31)	F002	BAP REIN 2	825.0	19.6	16210	51995	
1)	T026	CHILD CARE	700.0	.5	329	51824	
44)	A019	UNMCCS SA	706.0	54.3	39488	91224	
46)	T001	NAVAL WTHR	688.0	16.3	11244	102468	
94)	U093	CRAFT SHOP	638.0	2.9	1888	104268	
47)	T074	NEW SYSTEM	620.0	20.3	17846	121814	
19)	F004	FLY HR PGM	609.0	38.5	23100	144914	
35)	U034	ABCBA 3	600.0	20.0	11994	156910	
89)	T057	TSM	600.0	1.1	688	157598	
34)	E001	P2 MSN	580.0	13.4	6771	164369	← $250 MILLION
39)	R138	DEPOT MNT	560.0	342.9	121457	285826	
84)	D142	SPLY DP OP	500.0	297.8	148875	434701	
87)	U115	YANK UPGRD	500.0	6.7	3341	438042	
94)	F003	BAP REIN 3	462.0	11.9	5505	443547	
75)	U016	MAINT FACS	458.0	65.4	30415	481962	
10)	U155	AF SP-M&F	420.0	6.2	2586	484548	
28)	U026	NON-DIV EN	400.0	17.6	7853	491601	
88)	U012	CENTAG STG	375.0	96.5	36176	527777	← $500 MILLION
74)	U096	CONVERTERS	336.0	1.0	992	528769	
41)	T058	JOD TNG PK	310.0	7.3	2262	531031	
32)	U149	AN/TPS-29	300.0	58.1	18021	549052	
12)	U143	DYA SUBES	280.0	.0	0	549052	
42)	T064	BES SCHOOL	278.0	10.1	2770	551822	
31)	U150	MCOES	250.0	8.0	2062	553884	
37)	D143	SUPPLY MGT	250.0	48.1	12025	565949	
78)	E017	TRANSP SVC	240.0	4.5	1116	567065	
7)	U098	LIBRARY OP	245.0	1.1	268	567333	
23)	F128	USAR CD E8	240.0	14.7	3518	567851	
90)	T051	ADA THREAT	240.0	11.4	2731	570582	
73)	U120	BOILER PLT	225.0	20.4	4588	575682	
13)	F138	DACH MSG A	216.0	100.4	21678	597360	
24)	F097	ADT LODEX	218.0	2.5	524	596284	
67)	A033	SPT TRITAC	203.0	3.0	608	596884	
38)	D159	NEW EQP TR	200.0	23.0	4606	601490	
2)	T055	ACS UPGRAD	182.0	1.2	219	601709	
21)	F090	ARTS PROG	180.0	113.3	20392	622101	
8)	U078	ACS CCF	175.0	56.0	9798	631899	
60)	U002	JUP MAINT	175.0	12.9	2262	634161	
66)	D158	MAINT ENGR	167.0	438.6	73241	707402	
97)	A023	MIN	165.0	5.0	797	708199	
77)	U114	MAINT ADP	158.0	1.6	260	708459	
79)	E008	PERS SPT	158.0	10.5	1659	710118	
25)	F101	USAR TNG D	150.0	43.3	6499	716617	
33)	U111	GUARDRAIL	150.0	1.2	176	716793	
82)	F001	BAP REIN 1	149.0	3.7	544	717337	
48)	A024	ATC	148.0	10.4	1450	718787	
84)	D148	PROJ MGMT	135.0	132.4	17873	736660	
48)	A048	ATC 22 AAF	122.0	18.8	2298	738958	
20)	F018	USAR AN TR	120.0	87.3	10482	749440	
98)	A039	SPECOPS	120.0	.0	100	749540	← $750 MILLION
76)	U053	MASTER PLN	113.0	6.4	721	750261	
82)	F103	MSTR PLNG	113.0	52.2	5900	756161	
9)	U154	CHAPEL EQP	105.0	2.5	262	756423	
92)	M007	AUTOMATION	102.0	5.7	581	757004	
29)	U126	ALO INC 4	100.0	13.3	1330	758334	
61)	U116	NTRL MGT	100.0	5.3	526	758860	
85)	D150	CENT SPLY	90.0	63.7	5731	764591	
87)	D134	PROP DISP	90.0	589.9	52890	817481	
62)	U143	AOAP	83.0	1.4	117	817598	
81)	F130	GMAR-FORSM	77.0	149.6	11500	829598	
72)	T114	SYS STUDY	72.0	27.0	2000	831598	
93)	M016	MED EQUIP	72.0	19.7	1365	832963	
18)	E010	MEDICAL	70.0	17.5	1227	834190	
45)	T133	DP RENOVAT	69.0	93.5	3888	837198	
66)	F004	NTRL MAINT	67.0	116.0	7824	845614	
26)	F104	SC SPT TNG	66.0	84.2	5851	850865	
49)	A042	AUTADIN 2	66.0	18.2	1893	851158	
91)	A076	TECH CNTRL	66.0	26.0	1685	852763	
5)	T132	KP DCT/DST	56.2	171.0	10698	863461	
14)	F140	DACH MSG B	54.0	267.9	15000	878461	
96)	U121	IISC	52.0	84.9	4296	882787	
50)	A063	SATCOM	46.0	73.8	3698	886397	
17)	A072	MARS	44.0	42.6	3667	889464	
22)	F083	LAND ACS	43.0	16.7	750	890214	
68)	D147	IND PREP	42.0	2266.2	95181	985395	
51)	A064	ATCAP	40.0	52.5	2100	987495	
6)	U162	RPL TNT/M	38.0	12.9	483	987948	
11)	U159	DETAF /AU21	35.0	11.3	397	988345	
15)	D181	VOL F.O PGM	30.0	1.7	47	988392	
16)	D176	FMMA	30.0	122.1	3418	991810	← $1 BILLION
81)	F093	ENERGY PGM	28.0	755.5	21155	1012965	
71)	T094	BASE ENERG	23.0	303.1	6672	1019637	
86)	D179	CIV ED	23.0	18.1	417	1020054	
3)	T062	DP ED PROG	21.0	11.0	232	1020286	
69)	A070	OSHA-ACC	20.0	130.8	2617	1022903	
4)	T063	DP PLASTIC	7.0	35.7	250	1023153	
44)	T093	TNG ABLTY	7.0	1663.7	11646	1034799	
80)	F091	SMSA-FORSM	6.0	2796.8	16781	1051580	
70)	A082	OF-ACC	0.0	67.6	1300	1052710	

Table 3-3a

"MARKER" ISSUES SORTED BY BENEFIT

OVERALL ALLOCATION
30 MAR 79

	ITEM		BENEFIT	C/B	COST	CUM COST	
(2)	U163	DYA BUSES	200.0	.0	0	0	
1)	Y026	CHILD CARE	700.0	.5	329	329	
98)	A039	SPECOPS	120.0	.0	100	429	
27)	U001	NRC DEF	1400.0	.9	1297	1726	
7)	U098	LIBRARY OP	245.0	1.1	268	1994	
89)	Y057	TBM	600.0	1.1	680	2674	
33)	U111	GUARDRAIL	150.0	1.2	176	2850	
2)	Y055	ACS UPGRAD	182.0	1.2	219	3069	
62)	U143	ADAP	83.0	1.4	117	3186	
77)	U114	MAINT ADP	150.0	1.6	240	3446	
15)	B101	VOL ED POM	30.0	1.7	47	3493	
74)	U094	CONVERTERS	330.0	1.8	592	4085	
9)	U134	CHAPEL EQP	105.0	2.5	262	4347	
24)	F097	ADT LOOEY	210.0	2.5	524	4871	
94)	U093	CRAFT SHOP	430.0	2.9	1800	6671	
38)	U095	2 FLOAT BR	850.0	2.9	2454	9125	
67)	A033	SPT TRITAC	203.0	3.8	600	9725	
82)	F001	RAP REIN 1	149.0	3.7	544	10269	
78)	K017	TRANSP SVC	348.0	4.5	1116	11385	
47)	A023	WIN	166.0	5.0	797	12182	
61)	U116	MTRL MGT	100.0	5.3	526	12708	
92)	H007	AUTOMATION	102.0	5.7	581	13289	
10)	U135	AF SP-MSF	420.0	6.2	2586	15875	
76)	U053	MASTER PLN	113.0	6.4	721	16596	
57)	U115	TANK UPGRD	500.0	6.7	3341	19937	
41)	T058	JOB TNG PK	310.0	7.3	2262	22199	
31)	U150	MCOES	250.0	8.0	2002	24201	
42)	T064	REG SCHOOL	275.0	10.1	2770	26971	
98)	A026	ATC	140.0	10.4	1450	28421	
79)	K008	PERS SPT	158.0	10.5	1659	30080	
3)	T062	DP ED PROG	21.0	11.0	232	30312	
11)	U159	BETAF MUSI	35.0	11.3	397	30709	
88)	T051	ADA THREAT	240.0	11.4	2731	33440	
54)	F003	RAP REIN 3	462.0	11.9	5505	38945	
60)	U002	JUR MAINT	175.0	12.9	2262	41207	
6)	U142	RPL TNTRS	35.0	12.9	453	41660	
29)	U124	ALO INC 4	100.0	13.3	1330	42990	
36)	K001	P2 MBN	500.0	13.6	6779	49769	
21)	F120	USAR CD EQ	248.0	14.7	3518	53287	
48)	T001	NRML UTHR	600.0	16.3	11244	64531	
22)	F003	LAND ACQ	45.0	16.7	750	65281	
18)	K018	MEDICAL	78.0	17.5	1227	66508	
20)	U020	NON-DIV EN	400.0	17.6	7053	73561	
84)	B179	CIV ED	23.0	18.1	417	73978	
49)	A162	AUTODIN 2	60.0	18.2	1093	75071	
68)	A068	ATC 22 AAF	122.0	18.8	2298	77369	
93)	H016	MED EQUIP	72.0	19.0	1365	78734	
83)	F002	RAP REIN 2	825.0	19.6	16210	94944	
35)	U036	ARCSA 3	600.0	20.0	11996	106940	
73)	U120	BOILER PLT	25 .0	20.4	5600	111540	
30)	B159	NEW EQP TR	200.0	23.0	4606	116146	
91)	A076	TECH CNTRL	60.0	26.0	1605	117751	
72)	T114	SYS STUDY	72.0	27.8	2000	119751	
43)	T074	NEW SYSTEM	620.0	28.3	17546	137297	
55)	B094	CENT PRUCH	1000.0	31.5	31534	168831	
4)	T063	DP PLASTIC	7.0	35.7	250	169081	
19)	F004	FLY HR POM	600.0	38.5	23100	192181	
25)	F101	USAR TNG D	150.0	43.3	6499	198680	
45)	T133	DD RENOVAT	69.0	43.5	3000	201680	
37)	B143	SUPPLY MGT	250.0	48.1	12025	213705	
32)	U149	AN/TPS-29	300.0	50.1	15021	228726	
87)	F103	MBTR PLNG	113.0	52.2	5900	234626	
51)	A064	ATCAP	40.0	52.5	2100	236726	
8)	U070	ACS CCF	175.0	54.0	9798	246524	← $250 MILLION
44)	A019	UMMCCS BA	700.0	56.3	39488	285924	
17)	A072	MARS	99.0	62.6	3067	288991	
85)	B150	CENT SPLY	90.0	63.7	5731	294722	
70)	A082	GE-ACC	5.0	67.6	338	295060	
90)	A063	SAYCOM	50.0	73.0	3691	298750	
26)	F104	RC SPT TNG	60.0	84.2	5051	303801	
34)	U121	IIBB	50.0	84.9	4246	308047	
75)	U016	MAINT FACS	450.0	88.4	39415	346462	
28)	F010	USAR AN TR	120.0	87.3	10482	356944	
58)	U012	CENTeS STS	375.0	96.5	36176	393120	
13)	F138	BACH HBO A	218.0	100.4	21870	414990	
21)	F098	ARTS PROG	100.0	113.3	20392	435598	
64)	F084	MTRL MAINT	67.0	116.8	7824	443414	
16)	B176	FHMA	80.0	122.1	9818	453832	
69)	A088	OSHA-ACC	20.0	138.8	2617	456449	
96)	B148	PROJ MGMT	135.0	132.4	17873	466322	
83)	F138	BMAR-FORSM	79.0	149.4	11888	478122	
8)	T132	KP DCT/OST	56.0	191.0	10698	488820	
71)	T096	BASE ENERG	23.0	203.1	4672	493492	← $500 MILLION
39)	B130	DEPOT MNT	800.0	242.9	121457	614949	
14)	F148	BACH HBO B	84.0	267.9	15000	629949	← $750 MILLION
54)	B142	SPLY DP OP	500.0	297.8	140875	770824	
66)	B158	MAINT ENGR	167.0	438.6	73241	852065	
97)	U154	PROP DISP	98.0	887.9	83090	935155	
81)	F093	ENERGY POM	38.0	755.5	21135	956319	
46)	T093	INR ABLTY	7.0	1043.7	7946	933744	← $1 BILLION
65)	B147	INV PREP	62.0	2246.2	98181	1050937	
86)	F091	OSHA-FORSM	6.0	2796.8	16781	1067718	

Table 3-3b

"MARKER" ISSUES SORTED BY COST-BENEFIT

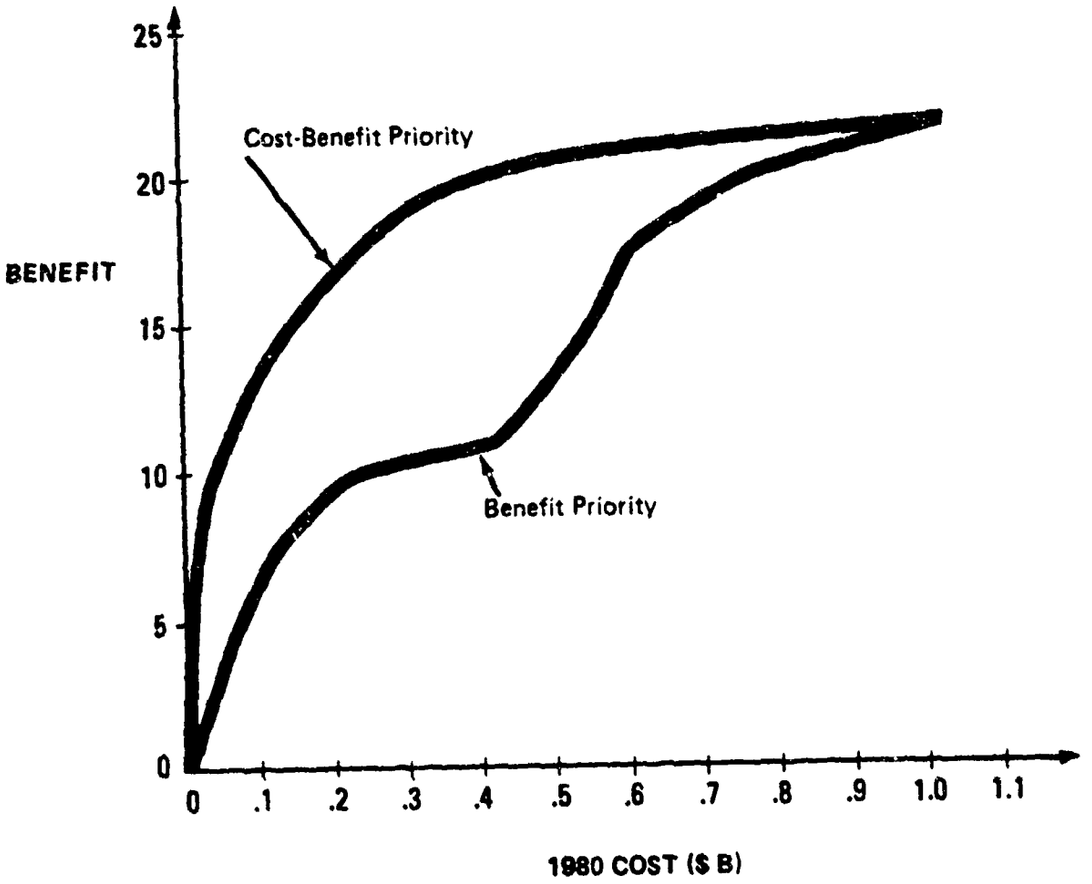


Figure 3-1

COST-BENEFIT VERSUS BENEFIT-ONLY CRITERIA –
PARR ISSUE "MARKER" LIST

Before the prioritization continued into the phase of integrating the remaining 247 PARR issues into the marker list, the participants were asked to supply written rationale for the relative placements of a portion of the marker items with respect to one another in the category marker lists. This written rationale is particularly important because it represents the only record of the reasons for certain evaluations. Should Congress, superiors, or anyone else question the particular ordering obtained, a record of the reasoning used is available. Therefore, it is particularly important that rationale be carefully prepared.

To integrate the 247 remaining PARR issues with those contained in the marker list, the participants evaluated the issues by functional category. That is, the remaining PARR issues for each functional category were compared with those of the same functional category in the marker list and assigned benefits. Hence, this process produced five separate lists of PARR issues (one for each functional category) with benefits assigned on a common scale.

Before the five category lists were integrated into a final overall benefit list, they were rank ordered with respect to benefit and cost-benefit. The costs assessed were the costs in thousands of dollars estimated for FY 80. The participants then studied the implications of these lists in terms of purchasing priority, and adjusted benefit values which led to seemingly inappropriate implications. Participants provided rationale to support the agreed-upon adjustments.

To complete the exercise, the category benefit lists were combined into a total PARR issue list. Although

cross-referencing among the five category lists would have provided the same amount of information, a single overall list facilitated a final validation of benefit values and their implications. This list could be used to establish buying priorities for all PARR issues across all functional categories.

Figure 3-2 displays, for the 334 PARR items, the cumulative cost versus cumulative benefit for both benefit-only and cost-benefit purchasing strategies. Once again, this display indicates that, in terms of benefit-purchasing power, the cost-benefit purchasing strategy clearly is more advantageous than the benefit-only strategy.

The final results of this PARR issue analysis and prioritization were an overall list of PARR issues ordered by benefit, an overall list of PARR issues ordered by cost-benefit, and supporting rationale for the marker issues.

Certain qualifications should be made regarding these data if they are to be used to guide PARR-issue spending decisions. First, the benefit assessments are subjective: They represent highly knowledgeable but nonetheless fallible analysts' judgments. Second, the cost figures used in the analysis included only one-year costs, and manpower costs were not included in the PARR data. In addition, manpower constraints were not considered in assessing costs or benefits. Finally, the entire analysis was performed in an exceedingly short (three-day) period.

In spite of the above limitations, the analysis has a number of strong points and potential uses. First, the analysis supplies a sound starting point for the decision process on PARR issues. Second, the cost-benefit consequences

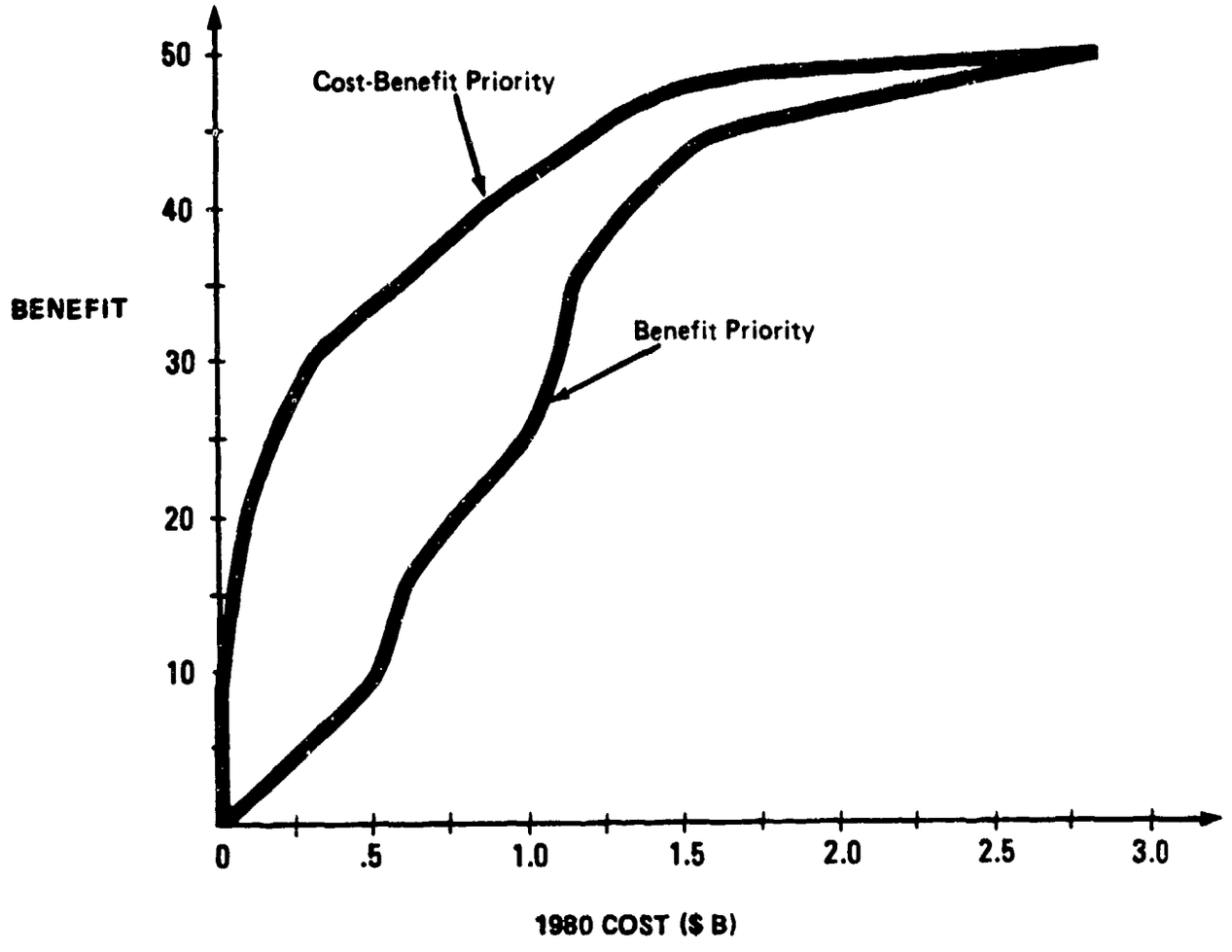


Figure 3-2

COST-BENEFIT VERSUS BENEFIT-ONLY CRITERIA – PARR ISSUES

are clearly visible, and the process used to derive them is a visible and reproducible one. Third, the analysis can be used as a communication aid, both in bringing into focus controversial PARR issues and in building a defense of PARR issues in the overall Army program development.

3.1.2 Evaluating the PARR prioritization - The PARR prioritization exercise can be looked upon as a largely successful effort during which all involved personnel made optimal use of the short period of time allotted to them. In the future, this exercise should be allotted at least a full week, and the following steps should be followed:

1. Prior to the exercise, common task-specific definitions should be established to ensure that similar items from the various commands appear in the same functional categories.

2. An education period should precede the exercise during which:

   a) all PARR issues are clearly explained and understood, including all issues, not just potential marker list issues;

   b) concise descriptions, in terms of "output," are written for all issues;

   c) the cost data are organized and validated.

3. The Army staff should select the marker issues and verify that they cover the full range of costs and benefits (functional category priorities).

4. The Army staff should develop benefit values for marker items within each functional category. As a general rule, the benefit values should have roughly the same range as the costs of the issues.

5. The staff should provide the marker lists to PA&ED, and PA&ED should integrate the separate marker lists into a single master list.

6. The staff and PA&ED should convene to resolve master marker list priorities.

7. The master marker list priorities should go before the Program Guidance Review Committee (PGRC) for approval.

8. The staff should develop benefit values for issues in each functional category and integrate these into the category benefit lists.

9. The staff should provide the total integrated issue lists, by functional categories, to PA&ED for integration into the final prioritized issue list.

If the above-suggested sequence of steps is followed, the PARR prioritization exercise should provide maximum information to those individuals making decisions on PARR issue expenditures.

3.1.3 Inter-expert reliability - Since the relative benefit numbers used in the cost-benefit analysis resulted from careful judgment rather than hard data, the question of inter-expert reliability is often raised. That is, how much agreement can be expected between the benefit numbers of two

qualified experts (or in the case of this exercise--two different groups of experts)? The question has not been investigated under the controlled conditions of an experiment, although it certainly could be done. However, two independent benefit scales for 106 of the 334 PARR issues were developed, one derived by the PARR issue prioritization just discussed, and the other developed by individuals within the directorates of the Deputy Chief of Staff for Operations (DCSOPS). The approach used for this prioritization was the same as that described in Section 2.1: Each directorate developed a benefit scale for the PARR issues it sponsors and then the seven benefit scales were merged into a single scale. Figure 3-3 shows the agreement of these two benefit scales, each point representing the benefit numbers of the two groups for a single PARR issue. The correlation coefficient between these two scales is 0.70, which suggests significant though not striking agreement.

3.2 POM Issue Prioritization

The objective of the POM analysis was to develop a cost-benefit prioritization of all PDIP's (approximately 185) being considered. There were ten sponsors or proponents:

1. DCSOPS — Deputy Chief of Staff for Operations
2. DCSRDA — Deputy Chief of Staff for Research, Development, and Acquisition
3. DCSPER — Deputy Chief of Staff for Personnel
4. OCAR — Office of the Chief of Army Reserve
5. NGB — National Guard Bureau
6. AAD — Army Automation Directorate

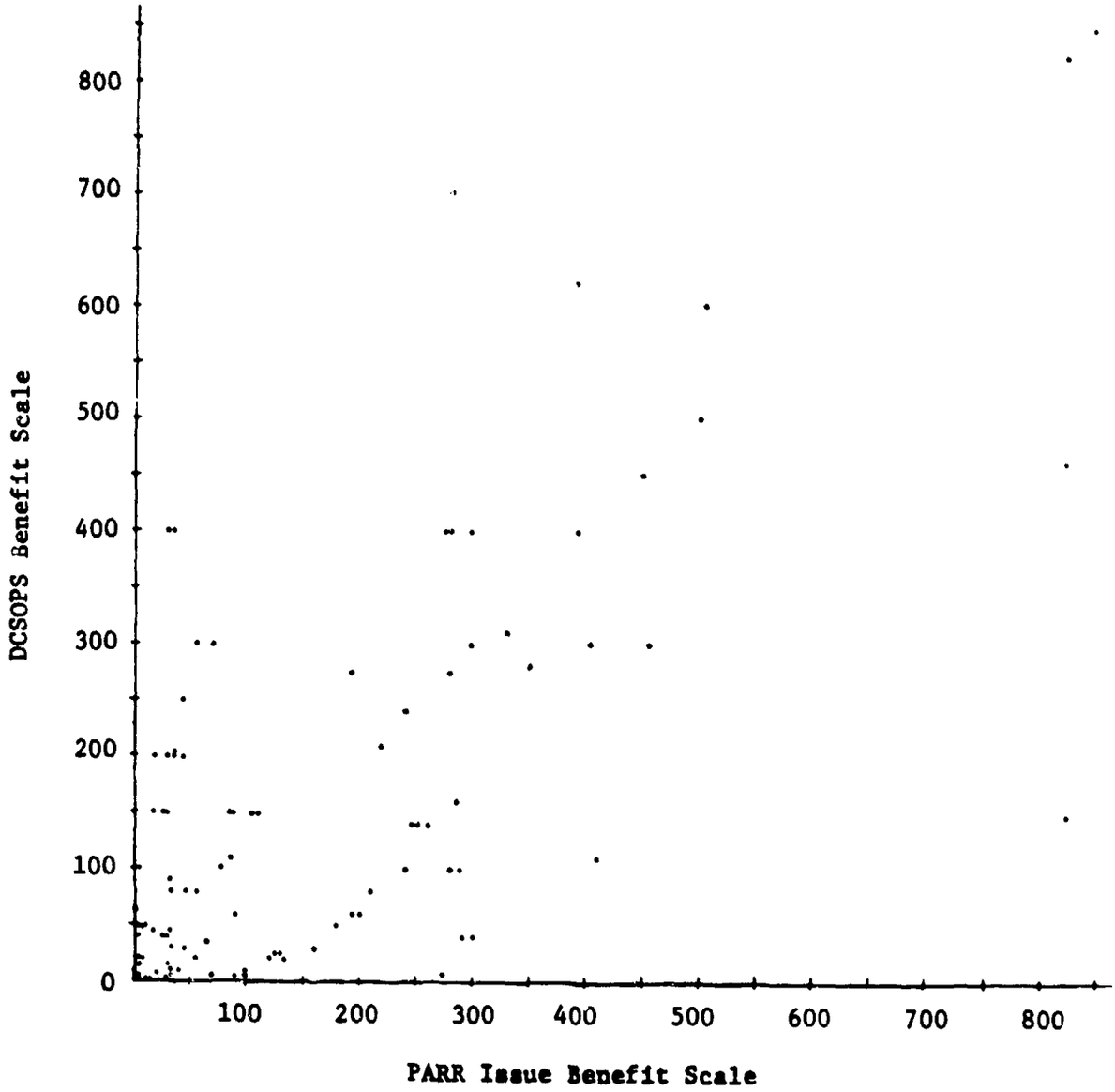


Figure 3-3
INTER-EXPERT RELIABILITY

7. DCSLOG Deputy Chief of Staff for Logistics

8. OCE Office of the Chief of Engineers

9. PA&ED Program Analysis and Evaluation Directorate

10. OTSG Office of the Surgeon General

Clearly, these proponents support a wide spectrum of PDIP's as evidenced by the examples in Table 3-4.

To illustrate the process each proponent used to assign relative benefits to his PDIP's, consider the PDIP's of AAD, described in Table 3-5 in terms of five-year cost, relative benefit numbers, and benefit/cost ratio. Based upon these costs and benefits, the cost-benefit priority order supported by AAD was:

1. Interoperability
2. VIABLE
3. Modernization I
4. Modernization II
5. Readiness
6. Mobilization
7. Modernization

The benefits reflect the following judgments:

- o VIABLE is equal to the other six PDIP's in benefit.
- o Interoperability is over twice as beneficial as the combination Modernization I and II, Readiness, Modernization, and Mobilization.

SPONSOR	PDIP TITLE
DCSOPS	National Training Center NATO Forward Deployed Readiness DS/GS Maintenance (USAREUR/FORSCOM) USAREUR DIV ALO Increase Flying Hour Program U.S. Contribution to NATO Military Budget
DCS RDA	M60 Tank Production GSRS REMBASS Air Cushion Vehicle (ACV)
DCSPER	Quality of Life Enhancement/ELIFE TAG No. 1 Women in the Army (WITA) Decision Package Set No. 40 Training Developments - Current Program Civilian Training, Education, and Development Program Organizational Effectiveness
OCAR	USAR Readiness (M to M + 30)
NGB	M to M + 30 Force
AAD	Readiness Automation Modernization Mobilization Automation Interoperability Project VIABLE, Phase 1 Automation Modernization I Automation Modernization II

Figure 3-4

REPRESENTATIVE SAMPLE OF PDIP'S

SPONSOR	PDIP TITLE
DCS LOG	Support Readiness - Property Accountability NATO Task Force: Consumer Logistics
OCE	Training/Operational Efficiency - MCA Sub-Package Construction in Panama - MCA Sub-Package Korea Relocation - MCA Backlog of Maintenance and Repair - Europe
PA&ED	Readiness #1 (PARR's) Management #1 (PARR's) Modernization #1 (PARR's) Materiel #1 (PARR's) Human #1 (PARR's)
OTSG	Preposition 18 Reserve Component General Hospitals in Europe Military Occupational Health/Safety Hazards International Health Initiatives

Table 3-4

REPRESENTATIVE SAMPLE OF PDIP's
(Continued)

PDIP	5-YEAR COST	BENEFIT	BENEFIT/ COST
VIABLE	147.	100.	0.68
Interoperability	30.	70.	2.3
Modernization II	35.	13.	0.37
Modernization I	18.	7.	0.39
Readiness	20.	5.	0.25
Modernization	232.	4.5	0.019
Mobilization	19.	0.5	0.26

Table 3-5

AAD'S RELATIVE COSTS AND BENEFITS

- o Modernization II is slightly more beneficial than Modernization I, Readiness, and Mobilization.

- o Modernization, Modernization I, and Readiness are more beneficial than Modernization II.

- o Readiness is equal in benefit to Modernization and Mobilization.

The benefit numbers for all sponsors were elicited over a two-week period by interacting with the action officers of each proponent.

At the conclusion of this two-week period, cross-sponsor benefit scalings were elicited from the "Rump" PGRC, during a session conducted according to the rules of engagement shown in Figure 3-4. The two scales contained a number of inconsistencies that were discussed with the "Rump" PGRC and subsequently resolved. Table 3-6 provides a cross-sponsor benefit scale for one PDIP from each sponsor's list in Table 3-4. This benefit scale is derived from the final benefit numbers of the POM prioritization. A set of judgments similar to those discussed above for packages of AAD's PDIP's can be constructed for the cross-sponsor PDIP's.

Following the cost-benefit analysis, the additional parameters discussed at the beginning of Section 3.0 were considered in developing deviations from the cost-benefit priorities. To the top-level decision makers, these deviations were both visible and quantifiable; thus, the impacts of political and other legitimate (non-mission) parameters are visible. This visibility provides the top-level decision makers with a means to grade the deviations that were made.

1. SPONSOR BENEFIT ORDER HAS BEEN SET BY THE SPONSOR AND DOES NOT CHANGE DURING CROSS-SPONSOR ASSESSMENT.

2. SPONSOR MAY CHANGE BENEFIT NUMBERS ONLY TO RESOLVE INCONSISTENCIES.

3. INCONSISTENCIES CAN BE RESOLVED BY CHANGES IN CROSS-SPONSOR BENEFIT ASSESSMENTS (ITERATIONS 1 AND 2) AND/OR SPONSOR BENEFIT ASSESSMENTS. GROUP DELPHI TECHNIQUES WILL BE USED TO MAKE CHANGES IN CROSS-SPONSOR BENEFIT ASSESSMENTS. THE SPONSOR WILL BE SOLELY RESPONSIBLE FOR CHANGES IN HIS BENEFIT ASSESSMENTS TO RESOLVE INCONSISTENCIES.

4. SPONSOR HAS SOLE RESPONSIBILITY FOR HIS PDIP STATEMENTS OF RATIONALE AND ANALYSIS. SPONSOR MAY CHANGE HIS STATEMENTS TO RESOLVE INCONSISTENCIES.

Figure 3-4

RULES OF ENGAGEMENT FOR CROSS-SPONSOR BENEFIT SCALING

SPONSOR	PDIP	CROSS-SPONSOR BENEFIT	5-YEAR COST	BENEFIT / COST
PA&ED	Readiness #1	100	134	.75
OCAR	USAR Readiness (M to M + 30)	81	165	.49
DCSOPS	DS/GS Maintenance	80	114	.70
NGB	M to M + 30 Force	79	552	.14
OCE	Construction in Panama	63	30	2.1
DCSPER	ELIFE	59	136	.43
AAD	VIABLE	34	147	.23
DCSRDA	M60 Tank Production	16	317	.050
OTSG	18 R.C. Hospitals - Europe	5.3	24	.22
DCSLOG	NATO T.F.: Consumer Logistics	2.5	66	.038

Table 3-6

CROSS-SPONSOR BENEFIT SCALE

Figure 3-5 presents a graphical comparison of the cost-benefit and the POM prioritizations. The vertical axis represents accumulated benefit as PDIP's are bought; the horizontal axis represents accumulated five-year cost. At the decrement level of funding, the POM order accounts for only half the benefit that the cost-benefit order does. The POM order parallels the cost-benefit order between the decrement and basic levels. As a result, the POM order results in two-thirds the benefit of the cost-benefit order. Several reasons for these differences are also listed in Figure 3-5.

Since OSD-directed initiatives, program imbalance, and the like directly affect development of the POM, it was recommended that this POM prioritization be viewed as the starting point, not the final outcome, of the POM decision-making process. This recommendation is based on the following:

- Benefit numbers represent only the Army's effectiveness. Attributes involving political, economic, and other issues must also be considered.

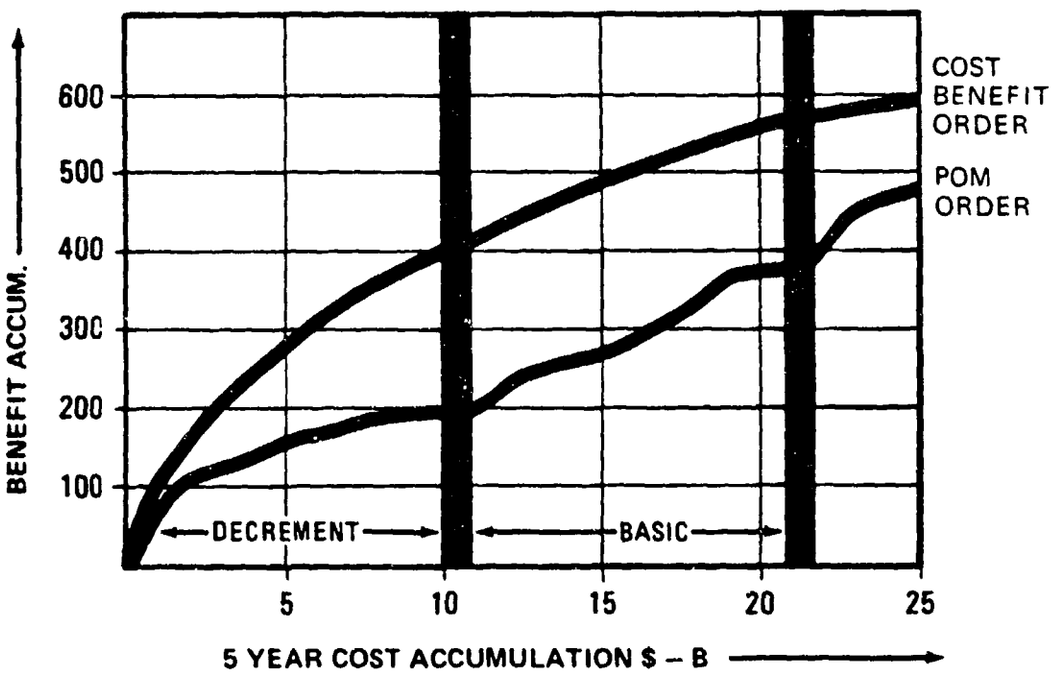
- Some of the PDIP's were dependent upon one another, such as the (1) creation and (2) deployment of a major unit.

- Only the five-year POM costs were used. Abnormally high outyear costs of certain PDIP's should be used to reduce their priority.

- Manpower constraints have to be considered in the final prioritization.

- This analysis is only conducted at the margin and therefore, does not flush out "gold watches" (soft

PROGRAM EVALUATION



Deviations . . . due to

- SOME OSD DIRECTED INITIATIVES
- MUST PAY BILLS
- PROGRAM IMBALANCE

Figure 3-5
COMPARISON OF POM WITH COST-BENEFIT ORDER

programs) in the core (that is, those programs not competing for funds between the minimum and enhanced fiscal constraints).

Additionally, the decision makers used this cost-benefit prioritization to determine how to spend $189M that had not been specifically earmarked in FY 80 at the basic level of funding built into the initial POM prioritization. This use of cost-benefit priorities enabled the decision makers to move the POM priority order closer to the cost-benefit priority order.

3.3 Evaluating the POM Prioritization

Better planning can significantly improve this process in three major areas: (1) packaging functional programs, (2) determining costs, and (3) eliciting benefits.

3.3.1 Packaging functional programs - Improving the packaging of functional programs involves several considerations. First, the functional programs must be structured so that they are independent of one another in terms of benefit and cost. For example, adding a force structure element and deploying that element should not be in separate programs or PDIP's. The best way to achieve this independence among programs is to more fully utilize the Army's organizational structure in the POM prioritization process.

Since the Army is such a large organization and the aggregation of functional programs is necessary for efficient management, the management of the packaging process for discrete functional programs is the second consideration. This packaging process should be hierarchical; that is, as one organizational element receives functional programs from

several lower level elements, it repackages the programs by using cross-element benefit numbers and the information provided by the lower elements about their programs. The organizational structure already exists within the Army staff; the problem is determining the best way to make it work for this "packaging" process.

Currently, several Army committees, such as the Research, Development, and Acquisition Committee (RDAC) and the Construction Requirements Review Committee (CRRC), rank sets of functional programs and feed these rankings into the POM process. Each committee uses certain procedures and/ or mathematical algorithms to transform the ordinal program rankings received from other organizational elements into an overall ordinal ranking of the programs falling within the committee's responsibility. Since the lower organizational elements manage their programs by procurement line items, their ranking process begins with procurement line items, not functional programs. The ammunition, guns, and vehicle/platform that comprise a weapon system (functional program) are separate line items. Typically, the complex ranking procedure is completed before line items are consolidated into functional programs. Line items that are eventually included in the same functional program often had very different initial rankings. This ranking of line items is wasted effort since functional programs are the essence of the POM product.

Defining functional programs (and even several levels within each functional program) from the many procurement line items should be the initial step. Each level of each functional program should be executable. While it is not possible to define these levels exactly, a close approximation can be developed. Then, a ratio benefit scale should be constructed for all levels of functional programs. The advantages of the benefit scale are that (1) it is easier to

integrate this form of prioritization with those of other sponsors; (2) it is clear that the priorities are based upon benefit to the Army and that cost can be factored into the decision-making process later; and (3) better rationale can be developed during the elicitation of a ratio benefit scale than during the formation of an ordinal ranking. Unfortunately, at the present time rationale developed for the ordinal rankings are never passed up the organizational ladder to be used in defense of the POM priorities. This lack of strong defense is considered by many to be a major weakness of the final POM product.

The final point to be made here is that because the benefit scale is defined over executable levels of functional programs, it only need be developed once. When the available monetary level changes, executable programs can be added or deleted as appropriate because the benefit judgments are independent of the constraint. However, the ordinal rankings currently developed are defined to meet a particular monetary constraint which changes repeatedly, requiring continual updating of the ordinal ranking.

Clearly, this packaging process must be started early (October or November), with the publication of the draft Army Planning Programming Guidance Memorandum, which provides uniform guidance on the decision process. An improved packaging structure should preclude the haphazard formulation of PDIP's; it should also ensure that items within a PDIP are similar in cost-benefit so that soft programs do not get a "free ride" with good programs.

If, in future years, the POM analysis continues to be done at the margin as it was this year, identifying exactly the contents of the core and communicating this

information to appropriate elements of the Army's hierarchical organization is the third consideration. Identifying and communicating this information has two beneficial aspects. First, the information helps sponsors assign benefits because it specifies how the Army will change if a given PDIP is funded. (Most of the PDIP's were "tips of icebergs," with the remainder of the iceberg located at the core. It is important that people involved in the POM analysis know the relative utility of the visible portion contained in the PDIP.) Second, close examination of the core is the best method for uncovering soft programs.

3.3.2 Determining costs - The determination of costs involved two aspects. The first was that the five-year POM costs were used as the cost of the PDIP's this year although the incremental life-cycle cost should have been used. The benefits of a PDIP corresponded to the life-cycle benefit associated with the tip of the iceberg defined by that PDIP. Therefore, the life-cycle cost associated with the tip of each iceberg should have been used as the cost of that PDIP. Clearly, many of these costs will not be incurred until the 1990's, and therefore, estimates of them will be very soft. Likewise, indirect costs associated with many programs should be factored in but are hard to estimate. These costs should be estimated and used in the cost-benefit prioritization, with the awareness that the priority location of the decision units with the softest costs can be identified as an issue and discussed at any point in the process.

The second factor in determining costs was that constant dollars (base-year uninflated dollars) should be used in calculating the life-cycle cost of the decision units. Current-year or FYDP dollars overemphasize the importance of dollars in the future. Discounting constant dollars, on the other hand, underemphasizes the importance of dollars in the future.

3.3.3 Eliciting benefits - The process of eliciting benefits requires a longer period of time than that given the sponsors and the cross-sponsor group during both the PARR and POM prioritizations. This can easily be accomplished with advanced planning; approximately two weeks is recommended for the PARR issues and three months (1 February - 1 May) for the POM prioritization. The major improvement to be made is the specification of a hierarchical framework to replace the benefit attributes. This can be structured to some extent through mission capabilities analyses. The analyses will be very useful in developing priorities for the many icebergs, however, and not as useful for prioritizing the different-size tips of these icebergs. A suggestion for this type of analysis is discussed in Section 4.0.

3.4 Budget Decision Package Prioritization

The cost-benefit procedure was determined to be inappropriate during the budget prioritization because the decision packages are based upon appropriation categories and therefore are not independent of each other in terms of value and cost. However, the results of the POM analysis were updated based upon the PDM and APDM of OSD. The PDM and APDM represent OSD's program directives within the three fiscal constraints: minimum, basic, and enhanced.

Then, to ensure that POM/PDM priorities matched the FY 80 budget priorities, the Director of the Army Budget (DAB) and PA&ED became responsible for comparing these two sets of priorities and pinpointing dissimilarities. If these dissimilarities proved critical to the execution of the functional programs, a resolution of the priorities was necessarily undertaken. Whereas PA&ED's interest is functional and concerned with the five POM years, DAB's interest lies in budget appropriations

for the budget year. The two groups must ensure that the implementation of a functional program is not delayed unknowingly by budget priorities. In addition, feedback from DAB is essential to PA&ED in setting POM priorities for the next year.

Altogether the prioritization of budget decision packages had to be developed within five different budget bands (constraints). These bands ranged from the minimum of the POM FY80 to the enhanced. The first three budget bands moved the Army budget from the POM minimum to the basic level. The final two bands moved the budget from the basic level to the enhanced level (see Figure 3-6).

The matching of POM and budget priorities was complicated by the fact that new functional programs (PDIP's) were being defined after the PDIP's were prioritized and the POM submitted to OSD. There were three sources of these new PDIP's: OSD, the Army's major commands, and the POM sponsors at Headquarters. OSD responded to the Army's POM by issuing a PDM and an APDM. Each of these documents contained some new programs that OSD wanted to include in the Army's prioritized PDIP's. So the Army established new PDIPs with priorities identified by OSD and then included these items in decision packages (see Figure 3-7).

The Army's major commands submitted Command Operating Budget Estimates (COBE's) to the DAB for preparation of the Army budget, and there were new functional programs identified in these documents. Finally, the Headquarters sponsors for the POM PDIP's were still identifying new functional programs that should have been prioritized after the POM submission. These functional programs were developed as decision packages for the budget prioritization and the new PDIP's were generated to describe them. When these PDIP's and decision packages

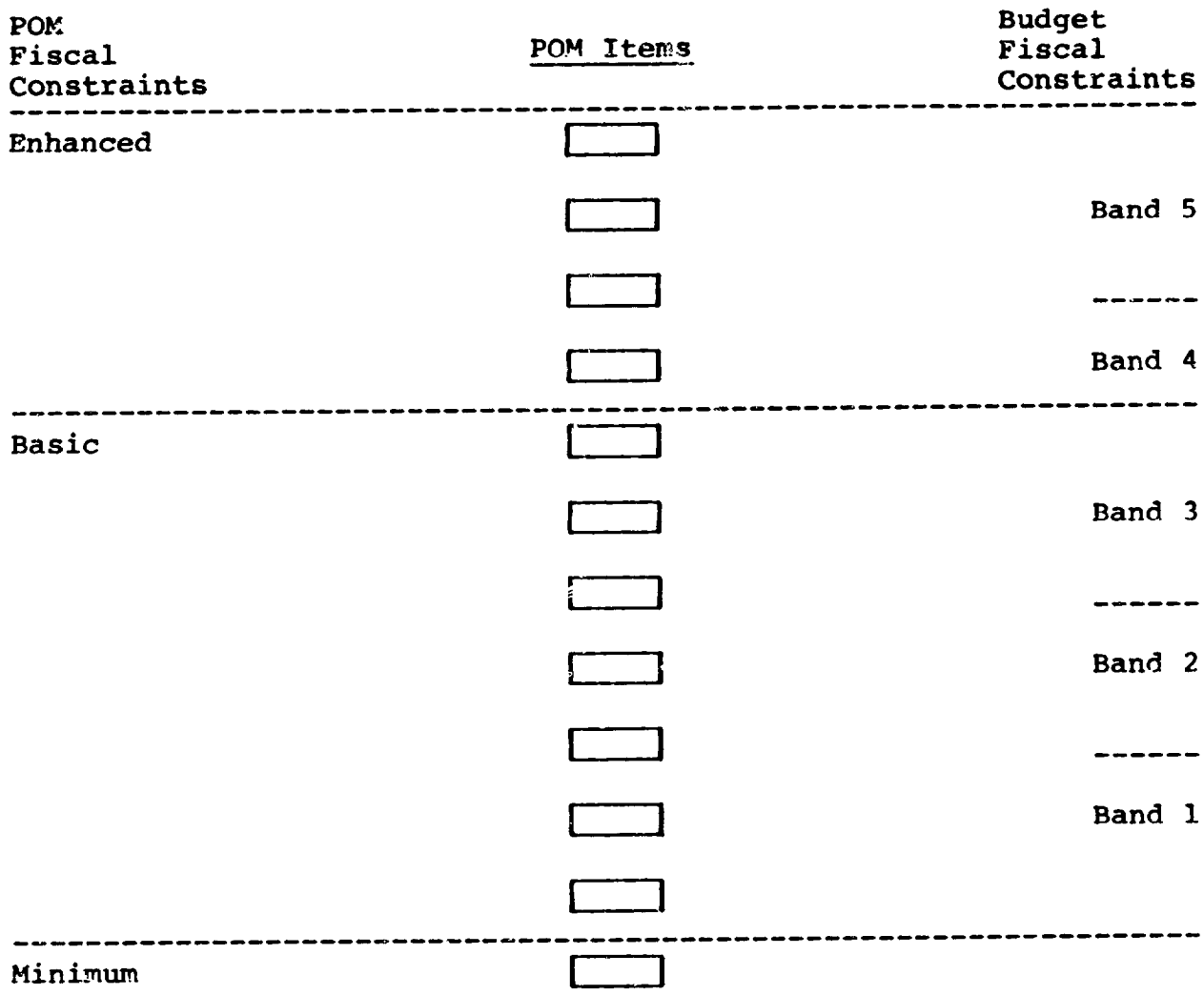


Figure 3-6

THE POM AND BUDGET FISCAL CONSTRAINTS

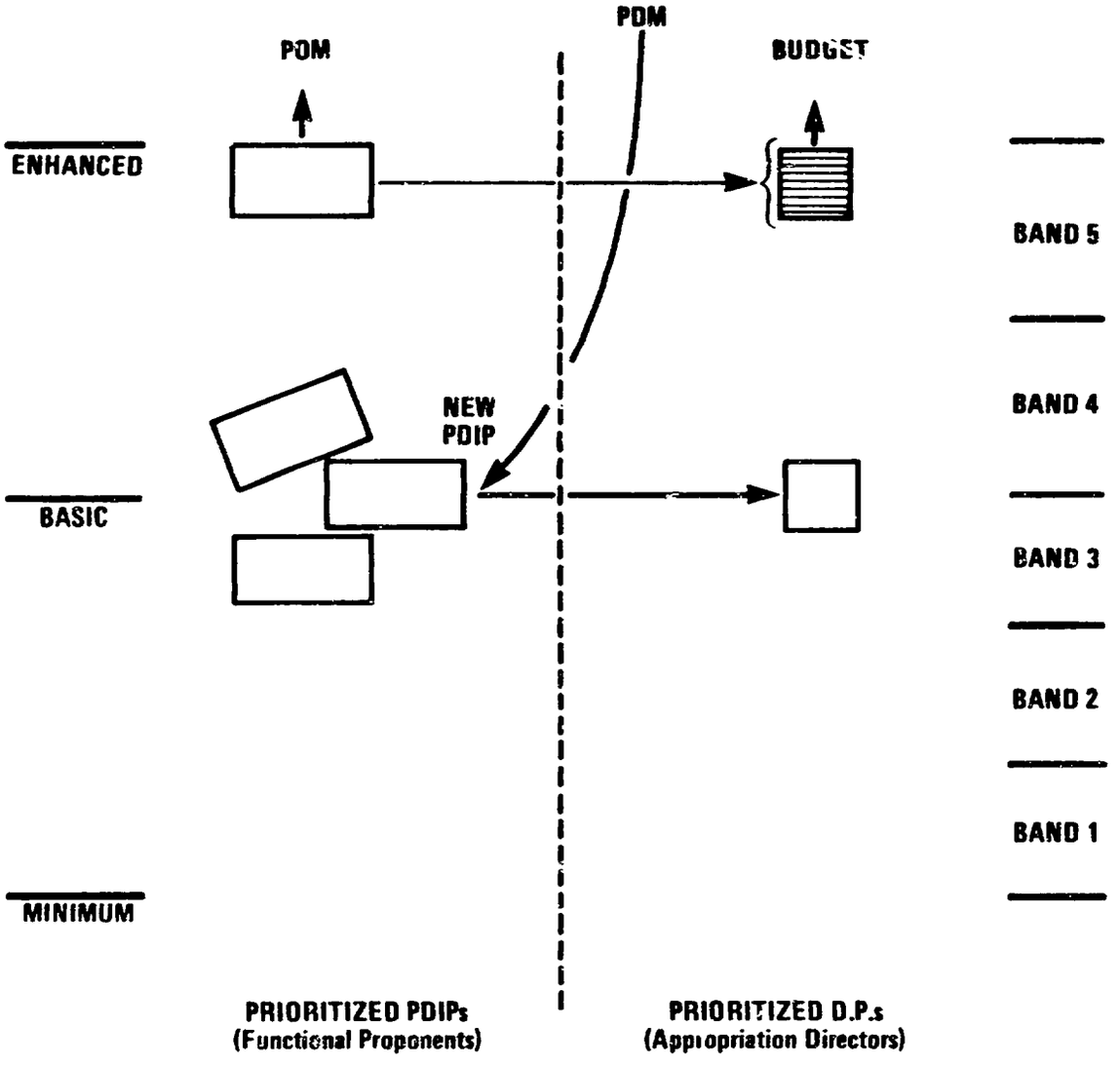


Figure 3-7
NEW PDIP IDENTIFICATION

were given their proper priorities, the priorities of the existing PDIP's and decision packages had to be adjusted as depicted in Figure 3-8.

In conjunction with this establishment of new PDIP's and decision packages, the correspondence between PDIP's and decision packages was made explicit. That is, the decision packages (or parts thereof) that corresponded to each PDIP were recorded so that POM and budget analysts could be assured that pieces of one functional program did not have widely disparate budget priorities in several decision packages, as shown in Figure 3-9.

The next step consists of submitting the budget and the revised POM to the Army's Budget Review Committee (BRC) for approval. The revised POM then provides a basis for the defense of the budget to prevent the reduction of particular appropriations that may affect functional programs comprising several appropriations categories.

3.5 Advantages of the Cost-Benefit Prioritization

The cost-benefit procedures used in these applications should, in theory, lead to better resource allocation decisions if valid benefit and cost information is used.

3.5.1 Justification of POM recommendations - The systematic assessment process that generated the benefits and produced the cost-benefit ordering of PDIP's also produced discussions and information that supported and justified the quantifications of benefit. The sponsors used this information to write concise supporting rationale for the benefit numbers assigned to each PDIP. This rationale is helpful when others ask for clarification of the benefit scale. Additional attributes

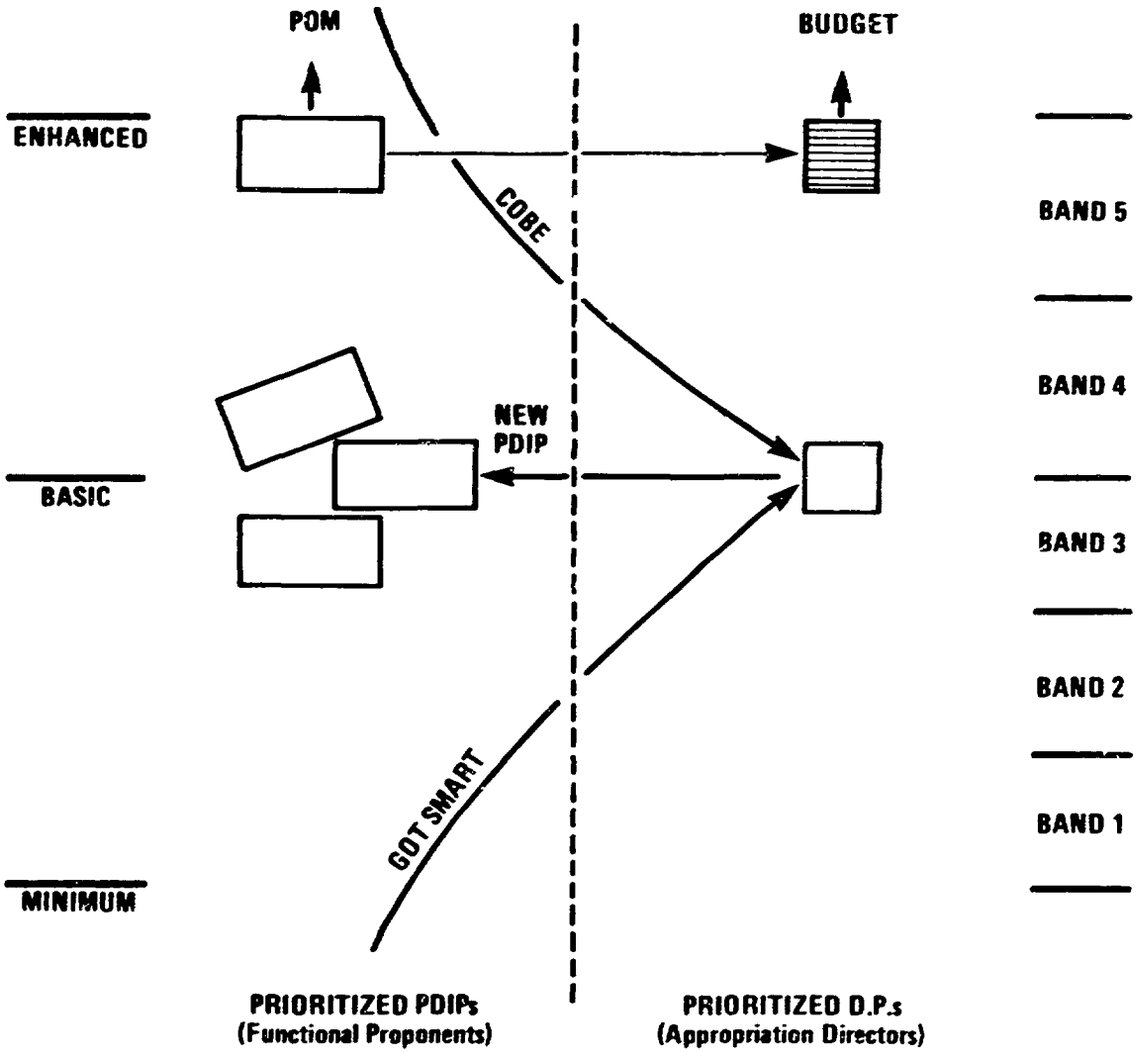


Figure 3-8

NEW DECISION PACKAGE IDENTIFICATION

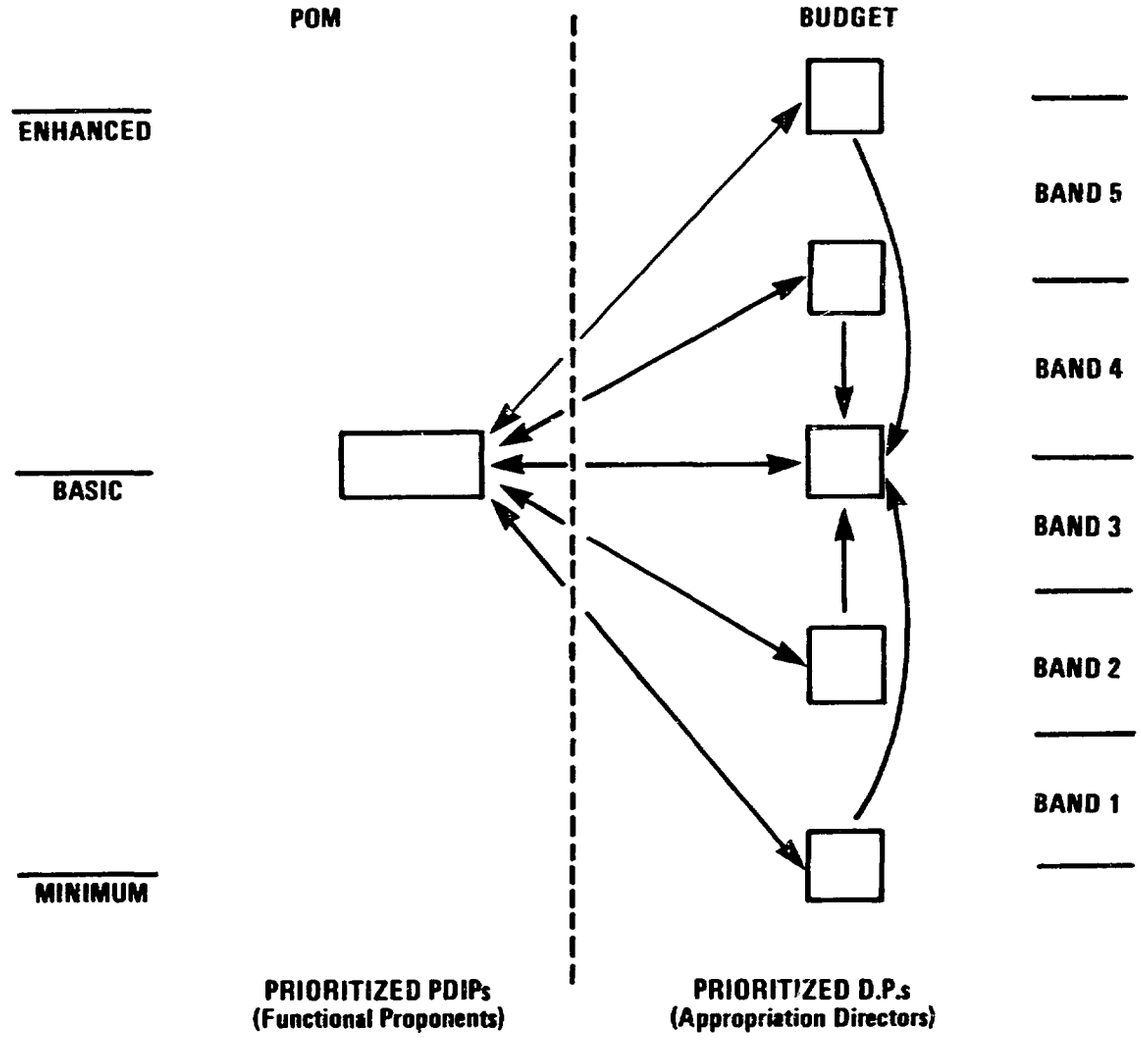


Figure 3-9

PDIP→DECISION PACKAGE TRACKING

of the cost-benefit assessment process are its responsiveness to requests for "what-if" analyses, and its adaptability to changes that may occur. The cost-benefit approach generates responsiveness and adaptability because the theory dictates the method for incorporating changes in funding when the fiscal constraint changes. In addition, questions about which PDIP's must be eliminated in order to fund others can be easily and effectively answered.

3.5.2 Availability of interactive computer support - An IBM 5110 mini-computer is programmed to do most of the calculations and data storage, retrieval, and manipulation needed by the working group responsible for preparation of the POM. The software in this computer is interactive in the sense that the officers reponsible for POM preparation can use it after a very short instructional period without the assistance of a computer programmer. They can make changes to the data and ask for new displays/printouts at their own convenience without relying on others or waiting in the queues often associated with large computer systems. The turn-around time is on the order of minutes or hours, and they can take the computer to meetings and briefings. This gives the officers a high level of confidence in the output of the computer because they are controlling both the inputs and the computer processing.

3.5.3 Identification of critical decision areas - The cost-benefit approach also facilitates the rapid identification of the real decision points; that is, that subset of PDIP's in the "gray area" of the decision-making process are readily discernible. Consequently, most of the subsequent discussion can be focused on the troublesome subset rather than spread evenly across all the PDIP's.

4.0 MISSION CAPABILITY ANALYSIS APPLICATIONS

The primary purpose for developing a hierarchical multi-attribute utility analysis across the Army's missions in support of the POM process is to provide guidance to proponents and the cross-proponent group for assigning benefit numbers to functional programs and PDIP's. No matter how the prioritization of PDIP's is done, a qualitative multi-attribute utility analysis would be helpful.

Section 4.1 describes the work DDI has done for TRADOC in support of the Battlefield Development Plan (BDP). This work provides a portion of the mission capability analysis needed to support the POM. Section 4.2 describes the initial attempt to do a complete Army mission analysis.

4.1 BDP Analysis

The multi-attribute utility analysis developed in support of the Battlefield Development Plan (BDP) was defined as dynamic force analysis. Dynamic force analysis was defined by analysts at TRADOC as the evaluation of the fighting effectiveness of a total force, such as an Army division or corps. Fighting effectiveness of a division is largely determined by the effectiveness of four elements: weapon systems, training systems, doctrine and tactics, and organizational (or force) structure. However, another important component of fighting effectiveness is comprised of the functions and tasks that the division must perform. For this analysis, Army experts defined the functions for a division as force generation and central battle. The tasks within force generation are to (1) gather intelligence about the movements of second-echelon Warsaw pact divisions; (2) interdict these enemy divisions before they get to a central

battle; (3) reconstitute the forces within the division between the central battles; (4) move the forces from one central battle to another; (5) provide command, control, and communication to orchestrate the generation of forces for the central battles presently underway or about to occur. The tasks within the central battle function are to (1) service the targets (tanks, personnel carriers, etc.) of the enemy; (2) provide suppression and counterfire to combat the enemy's artillery; (3) provide air defense coverage; (4) support the division forces in the central battle with ammunition, fuel, and medical services as needed; and (5) provide command, control, and communications, and electronic warfare support to the division forces.

The purpose of this dynamic force analysis was to evaluate the relative importance to force effectiveness of incremental improvements within each of the above-described tasks and to determine which tasks need the greatest improvement to upgrade the current division to an ideal fighting force. An evaluation spanning vastly different domains within a division--such as intelligence, interdiction, and target servicing--has rarely been done and has never been done systematically and explicitly for weapon systems, training systems, doctrine and tactics, and organizational structure either individually or totally.

The multi-attribute utility model structure for dynamic force analysis is depicted in Figure 4-1. Four levels of conditioning variables (type of conflict, enemy technology level, environment, and mission) were defined before the duties (functions and tasks) of the division were evaluated. (System parameters were not identified in this model due to time constraints for the analysis.) Therefore, the utility scales at the bottom of each path through the tree were

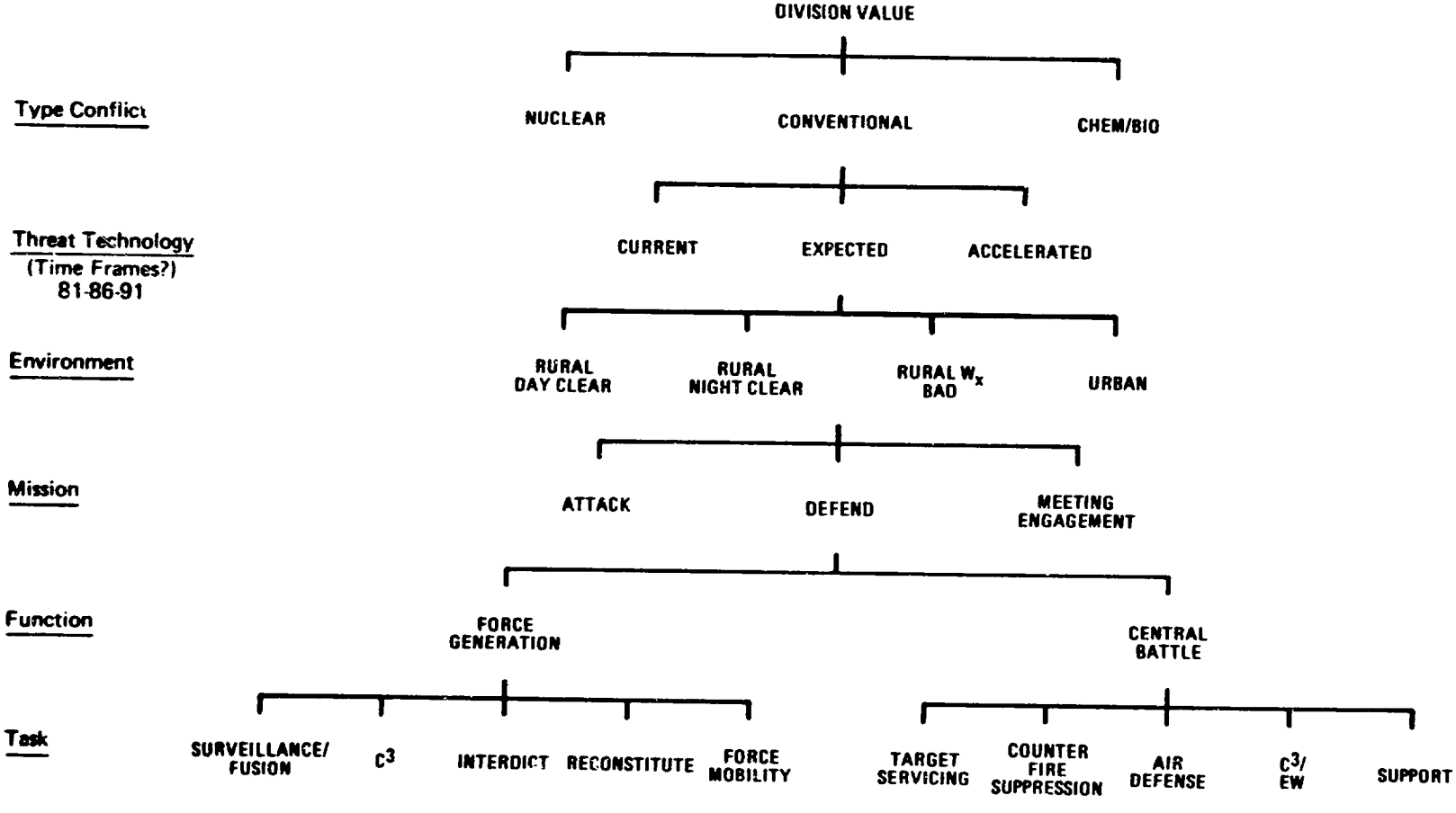


Figure 4-1

DYNAMIC FORCE ANALYSIS STRUCTURE

identified as shown in Figure 4-2. The baseline or zero utility level is the current (1980) division capability for a given task (such as air defense) based on four levels of conditioning variables. An ideal 1990 capability was defined for each task and given a utility score of 100. The weights assigned to the five tasks under each function for a set of conditioning variables reflected the relative magnitudes of division deficiency or improvement potential between the current and ideal capabilities. For example, the weights in Table 4-1 imply:

(1) Surveillance/fusion deficiency is twice as great as that of C^3.

(2) Surveillance/fusion deficiency equals that of C^3, interdiction, and reconstitution combined.

(3) C^3 deficiency equals that of interdiction and reconstitution combined.

Task	Weight
Surveillance/fusion	100
C^3	50
Interdiction	40
Reconstitution	10
Force Mobility	5

TASK WEIGHTS
Table 4-1

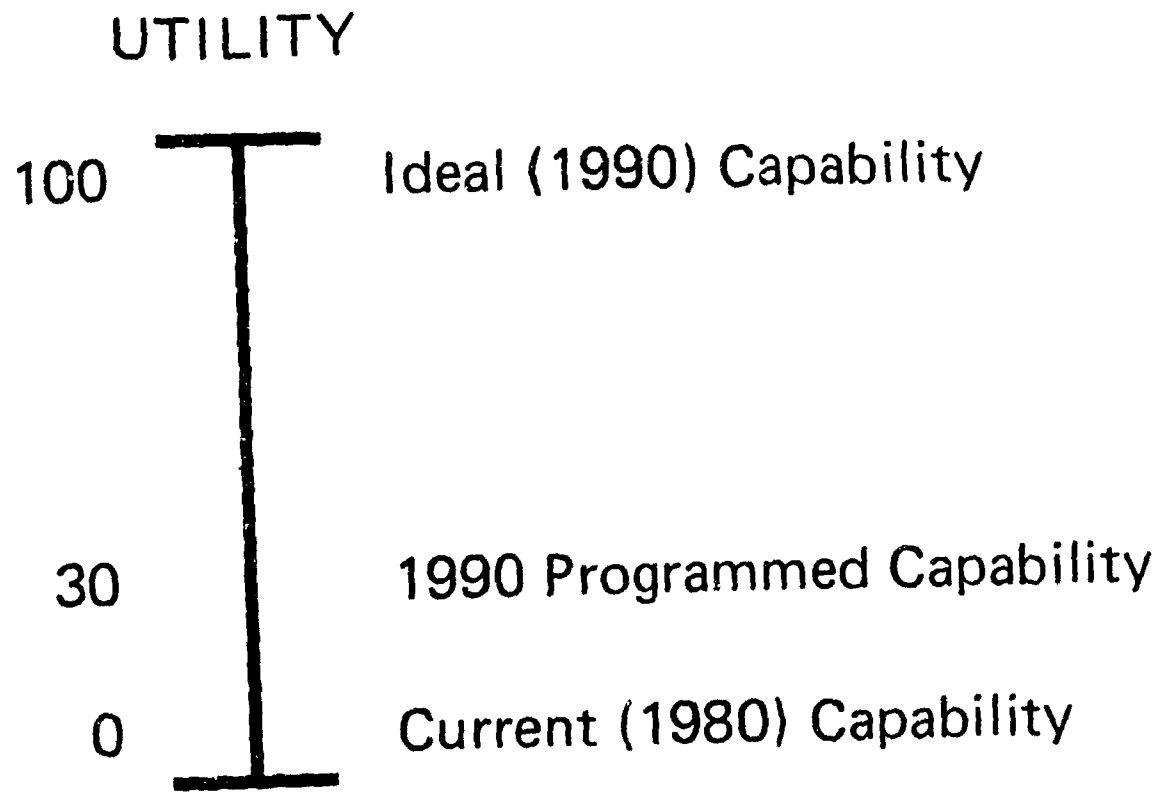


Figure 4-2
UTILITY SCALES

Finally, judgments were made concerning the percent improvement between current and ideal that the systems programmed by the Army will make to the division. These judgments were then used to compute the remaining deficiency of each task in 1990 after the programmed systems become part of the division.

Judgments were elicited from over thirty Army officers by using the multi-attribute utility structure described above. The judgments were summarized according to the formats of Tables 4-2 through 4-4. The actual numbers were omitted from these tables for classification reasons.

4.2 Complete Mission Capability Analysis

The four levels of conditioning variables in the BDP analysis were followed by the force generation and central battle phases of a division-level conflict; each phase has five distinct tasks. A more complete analysis would expand the conditioning variables; Table 4-5 provides a more complete list of potential conditioning variables. For an efficient multi-attribute utility analysis, conditioning variables would have to be packaged into scenarios.

The two phases of conflict in the BDP were part of the Army's ultimate mission to conduct war. There are, however, two ancillary or support missions. In the first, the Army is to act as a deterrent by its presence; this is primarily associated with the North Atlantic Treaty Organization (NATO). The second mission is the mobilization and injection of Continental United States (CONUS) forces into the conflict. In the deterrence mission, the primary goal is to maintain

TASKS		DEFICIENCIES	
		CURRENT	REMAINING
FORCE GENERATION	Surveillance/Fusion	•	•
	C^3	•	•
	Interdiction	•	•
	Reconstitution	•	•
	Force Mobility	•	•
	Sub-Total	•	•
CENTRAL BATTLE	Target Servicing	•	•
	Counter Fire	•	•
	Air Defense	•	•
	C^3/EW	•	•
	Support	•	•
	Sub-Total	•	•
TOTAL		•	•

Table 4-2
OVERALL TASK DEFICIENCIES

PHASE	TASK	CONVENTIONAL		NUCLEAR		CHEM/BIO	
		CURRENT DEFICIENCY	REMAINING DEFICIENCY	CURRENT DEFICIENCY	REMAINING DEFICIENCY	CURRENT DEFICIENCY	REMAINING DEFICIENCY
FORCE GENERATION	Surveillance/Fusion	•	•	•	•	•	•
	C^3	•	•	•	•	•	•
	Interdiction	•	•	•	•	•	•
	Reconstitution	•	•	•	•	•	•
	Force Mobility	•	•	•	•	•	•
	Sub-Total	•	•	•	•	•	•
CENTRAL BATTLE	Target Servicing	•	•	•	•	•	•
	Counter Fire	•	•	•	•	•	•
	Air Defense	•	•	•	•	•	•
	C^3/EW	•	•	•	•	•	•
	Support	•	•	•	•	•	•
	Sub-Total	•	•	•	•	•	•
	TOTAL	100		100		100	

Table 4-3

TASK DEFICIENCIES BY CONFLICT TYPE

CONVENTIONAL CONFLICT

PHASE	TASK	ATTACK		DEFEND		MEETING ENGAGEMENT	
		CURRENT DEFICIENCY	REMAINING DEFICIENCY	CURRENT DEFICIENCY	REMAINING DEFICIENCY	CURRENT DEFICIENCY	REMAINING DEFICIENCY
FORCE GENERATION	Surveillance/Fusion	•	•	•	•	•	•
	C^3	•	•	•	•	•	•
	Interdiction	•	•	•	•	•	•
	Reconstitution	•	•	•	•	•	•
	Force Mobility	•	•	•	•	•	•
	Sub-Total	•	•	•	•	•	•
CENTRAL BATTLE	Target Servicing	•	•	•	•	•	•
	Counter Fire	•	•	•	•	•	•
	Air Defense	•	•	•	•	•	•
	C^3/EW	•	•	•	•	•	•
	Support	•	•	•	•	•	•
	Sub-Total	•	•	•	•	•	•
	TOTAL	100	•	100	•	100	•

Table 4-4

TASK DEFICIENCIES BY MISSION

VARIABLES	SETTINGS		
Conflict Type	Conventional	Nuclear	Chem/Bio
Threat	Current	Expected	Accelerated
Location	NATO	Asia	Mideast
Conflict Duration (days)	0 – 30	30 – 90	90+
Warning Time (days)	0	7	14
Conflict Occurrence	1979 –1980	1981 – 1983	1984+

Table 4-5

CONDITIONING VARIABLES

readiness in terms of trained and motivated soldiers (quality of life issues impact here), as well as maintained equipment. All of the elements of the first support mission are present in the second one as well as installation and personnel support and the logistics base.

A capability analysis at these levels would benefit the POM and budget processes in two ways. First, as mentioned previously, it would aid in the assessment of benefit numbers for PDIP's and functional programs. Second, a Support Packaging Methodology, similar to the Force Packaging Methodology, could be developed to help establish levels of functional packages for the support services offered by proponents such as DCSPER and DCSLOG.

5.0 COMMENTS

5.1 Deviations from the Cost-Benefit Prioritization

Section 3.2 discussed the reasons for the Army to deviate from the cost-benefit priority, including:

- OSD Directives,
- must-pay bills (these should be scrubbed thoroughly),
- program imbalance,
- manpower constraints,
- Congressional priorities,
- production-line considerations,
- prior commitments (these should be scrubbed thoroughly), and
- national and regional economic implications.

The recommended approach is to develop the cost-benefit prioritization by using Army effectiveness as the definition of benefit. Only by doing this first can the Army communicate to others its priorities. Then, programs impacted by the above considerations should be identified as issues and moved up or down the priority list on an issue-by-issue basis. These considerations will always be input into the final determination of the Army budget and POM. However,

the better the initial Army priorities are, the closer the final priorities will be to the "true" Army priorities; thus it is important to have a good initial ranking.

5.2 Managing the Continuum

Managing the continuum embodies several issues, all focusing on the life-cycle nature of Army programs. First, the decision makers must address how effective the programs are in meeting current and future needs, as well as how supportable they are now and will be in the future. This means focusing on the life-cycle costs and benefits, not just on the current costs and benefits.

The dual focus on present and future is essential for both the POM and the Budget. Since the budget process focuses narrowly on 1980 costs, the importance of outyear costs and benefits can easily be downplayed. The POM process should be organized well enough to be usable in the budget process so that the life-cycle focus is not lost. The carryover from the POM to the Budget necessitates a change in language and managers; this provides the perfect opportunity for disconnects and improves the chances that the budget process will focus narrowly on the budget year rather than on the continuum.

5.3 Decision Tracking

Decision tracking is a mechanism for providing feedback to the decision makers concerning the impact of the resources they have allocated. Army decision makers are now making decisions for a budget in FY 80. Concurrently, the FY 78 budget is being spent, and the President and Congress are changing and approving the FY 79 budget. However, these

decision makers are not receiving good feedback about the impacts of the funds expended in FY 77 and FY 78. The establishment of a mechanism to provide the right amount and detail of feedback to the appropriate decision makers is necessary to improve the concept of cost and mission benefit when developing future POM's.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The cost-benefit prioritization process based on decision-analytic techniques uses the current staff organization without requiring any adaptations. In fact, the process is nothing more than a highly disciplined staff action using the relevant expertise of each staff element.

This prioritization process has been developed and tested within the Army during the PARR and POM processes. The POM priorities were updated during the budget preparation by using the POM and MACOM inputs. In addition, this process is applicable to other Army resource allocation procedures and committees (such as the RDAC, CRRC, SIPC, and BRC). Other decision-analytic techniques could well be applicable at other decision-making levels within the Army and should be investigated.

The action officers and the general officers have responded favorably to the prioritization process. In fact, many would have preferred to abandon the POM priority list for the cost-benefit priority list, and then determine deviations as discussed in Section 5.1. The advantages of using the cost-benefit procedure are:

- POM is more justifiable and defensible because:
  - the cost-benefit approach is fiscally responsible;
  - better rationale for the importance of the PDIP's is provided;

- response time for "what-if" analyses is short;

- sensitivity analyses can be conducted easily.

o Responsive computer support for management decision making is assured.

o Identification of the critical decision areas is provided since:

  - attributes other than Army effectiveness can be factored in systematically;

  - PDIP's around the decremented, basic, and enhanced funding levels can be scrutinized.

The decision analyst involved in the cost-benefit analysis is a facilitator who provides a structure and expertise for quantifying the judgments of the content experts. The Army staff provides the many levels of this content expertise, the requirements of which parallel the current Army staff organization structure. This procedure provides a structure and a discipline for the expertise of all elements of the Army staff.

6.2 Recommendations

As part of the POM preparation, the Army must develop a priority ranking of the functional programs within the fiscal constraints provided by OSD. This constitutes an analysis around the margin of the final constraints imposed to determine how the Army will spend its money. Since the Army's needs always exceed the capability permitted by the

fiscal constraints, this marginal analysis should be based upon the relative cost-benefit of the functional programs to ensure that the Army derives maximum benefit within the limits of these constraints. Initially, the priorities developed should be based solely upon the relative benefit to the Army of these functional programs. Then, these priorities can be modified to reflect the many economic/ political influences that are important to society as a whole.

The success of the cost-benefit prioritization procedures described in this report indicates that these analytical techniques should be codified and adopted as the Army prioritization system. Our recommended course of action for accomplishing this is the following:

(1) The DA should determine the macro parameters involved in codifying the process.

(2) The Force Packaging Methodology and Army Goals should be used as the initial framework with which to institute this process.

(3) Improvements to this framework should be derived from both experience with the process and the results of total mission capability analysis as described in Section 2.2.

Finally, a complete Army mission capability analysis should be conducted to prioritize the current deficiencies or needs across the Army's missions. Such an analysis would be useful in POM preparation because it would provide the proponents and PA&ED a common basis for developing the benefit scales and rankings of functional programs. Also, a Support

Packaging Methodology could be developed from it to augment the Force Packaging Methodology.

CONTRACT DISTRIBUTION LIST
(Unclassified Technical Reports)

2 copies

Director
Advanced Research Projects Agency
Attention: Program Management Office
1400 Wilson Boulevard
Arlington, Virginia 22209

3 copies

Office of Naval Research
Attention: Code 455
800 North Quincy Street
Arlington, Virginia 22217

12 copies

Defense Documentation Center
Attention: DDC-TC
Cameron Station
Alexandria, Virginia 22314

1 copy

DCASMA Baltimore Office
Attention: Mr. K. Gerasim
300 East Joppa Road
Towson, Maryland 21204

6 copies

Director
Naval Research Laboratory
Attention: Code 2627
Washington, D.C. 20375

SUPPLEMENTAL DISTRIBUTION LIST

Schools and Centers

US Army Command and
General Staff College
Ft. Leavenworth, KS 66027

US Army Combined Arms Center
Ft. Leavenworth, KS 66027

Department of the Army
US Army Logistics Management Center
Attn: DRXMC-LS-SCAD (ORSA)
Ft. Lee, VA 23801

US Army Administration Center
Ft. Benjamin Harrison, IN 46216

US Army Finance and Accounting
Center
Ft. Benjamin Harrison, IN 46216

US Army War College (SSISG)
Carlisle Barracks, PA 17013

US Army War College (Library)
Carlisle Barracks, PA 17013

United States Military Academy
Attn: Col. A. F. Grum
West Point, NY 10996

MAJOR COMMANDS

HQ, Army Materiel Development
& Readiness Comm. (DARCOM)
5001 Eisenhower Avenue
Alexandria, VA 22333

HQ TRADOC
Attn: ATRM-PA
Ft. Monroe, VA 23651

US ARMY COMMANDS/AGENCIES (CONUS)

US Army Communications Command
Attn: DCOC-PBB
The Pentagon
Washington, D. C. 20310

US Army Computer Systems
Command
Ft. Belvoir, VA 22060

Health Services Command
Clinical Medical Div./US Army
Pentagon Building
Washington, D. C. 20310

US Army Concepts Analysis
Agency (SSA)
8120 Woodmont Avenue
Bethesda, MD 20014

US Army Management System
Support Agency (SSA)
The Pentagon, Room BD1028
Washington, D. C. 20310

Other

Defense Logistics Studies
Information Exchange
Cameron Station
Alexandria, VA 22314

Management Information Systems
Directorate
Pentagon Building, Room 2C869A
Washington, D. C. 20310

US Army Engineer Studies Center
6500 Brookes Lane
Washington, D. C. 20315

US Army Research Institute
Organizations and Systems
Research Laboratory
Attn: Dr. Edgar M. Johnson
5001 Eisenhower Avenue
Alexandria, VA 22333

Air University Library
Maxwell AFB, AL 36112

US Army Forces Command, HQ
Attn: AFCS-PA
Ft. McPherson, GA 30330

Eighth US Army
Attn: ACS-OPS (CJ-FD)
APO San Francisco, CA 96301

HQ USAREUR/7th US Army
Attn: AEAGF-P
ODCSRM-RRAD
APO, NY 09403

HQUSARJ
APO San Francisco, CA 96343

Director, Center for Advanced
Research
Naval War College
Newport, RI 02840

Naval Postgraduate School
Attn: Patrick C. Parker
Monterey, CA 93940

Marine Corps Development and
Education Command
Quantico, VA 22134

HQDA Director PA&E
Army Chief of Staff
Attn: Lt. Col. Rapp
The Pentagon
Washington, D. C. 20310

DEPARTMENT OF DEFENSE

Director, Defense Program
Analysis & Evaluation
The Pentagon, 3E966
Washington, D. C. 20310

Director, Defense Advanced
Research Projects Agency
1400 Wilson Boulevard
Arlington, VA 22209

National War College
Ft. McNair
4th and P Streets, SW
Washington, D. C. 20319

Armed Forces Staff College
Norfolk, VA 23511

Defense Documentation Center
Attn: DDC-TC
Cameron Station
Alexandria, VA 22314

Defense Systems Management
School
Ft. Belvoir, VA 22060

HEADQUARTERS, DEPARTMENT OF
THE ARMY

Office Under Secretary of the Army
Pentagon Building, Room 3E732
Washington, D. C. 20310

Deputy Under Secretary of the
Army (OR)
Pentagon Building, Room 2E614
Washington, D. C. 20310

Assistant Secretary of the Army
(IL&FM)
Pentagon Building, Room 3E606
Washington, D. C. 20310

Assistant Secretary of the Army
(M&RA)
Pentagon Building, Room 2E594
Washington, D. C. 20310

Assistant Secretary of the Army
(RDA)
Pentagon Building, Room 2E672
Washington, D. C. 20310

Director of the Army Staff
Pentagon Building, Room 3E668
Washington, D. C. 20310

Assistant Chief of Staff for
Intelligence
Pentagon Building, Room 2E464
Washington, D. C. 20310

Deputy Chief of Staff for
Personnel
Pentagon Building, Room 2E736
Washington, D. C. 20310

Deputy Chief of Staff for
Logistics
Pentagon Building, Room 3E560
Washington, D. C. 20310

Deputy Chief of Staff for
Operations and Plans
Pentagon Building, Room 3E634
Washington, D. C. 20310

Deputy Chief of Staff for Research,
Development and Acquisitions
Pentagon Building, Room 2E672
Washington, D. C. 20310

Comptroller of the Army
Pentagon Building, Room 3A712
Washington, D. C. 20310

Chief of Engineers
Forrestal Building
1000 Independence Ave., SW
Room 4A245
Washington, D. C. 20314

Office of the Surgeon General (MI)
Pentagon Building, Room 3E468
Washington, D. C. 20310

Office of the Inspector General
Pentagon Building, Room 1E732
Washington, D. C. 20310

The Army Library (ASDIRS)
The Pentagon, Room 1A534
Washington, D. C. 20310

Office of the Chief of Legislative
Liaison
Pentagon Building, Room 2C631
Washington, D. C. 20310

Assistant Chief of Staff for
Automation and Communications
Pentagon Building
Washington, D. C. 20310

Task Force Management Office
Pentagon Building
Washington, D. C. 20310

U. S. Army Audit Agency
Nassiff Building
5611 Columbia Pike
Falls Church, VA 22041

Department of the Army and
Air Force
National Guard Bureau
The Pentagon, Room 2E394
Washington, D. C. 20310

Office of the Chief, Army
Reserves
The Pentagon, Room 3E390
Washington, D. C. 20310

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: TR-78-10-72	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): APPLICATIONS OF DECISION ANALYSIS TO THE U. S. ARMY AFFORDABILITY STUDY	5. TYPE OF REPORT & PERIOD COVERED: Technical Report
6. PERFORMING ORG. REPORT NUMBER	
7. AUTHOR(s): D. M. Buede, M. L. Donnell, H. Feuerwerger, J. E. Ragland	8. CONTRACT OR GRANT NUMBER(s): N00014-78-C-0100, ARPA Order No. 3469
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Decisions & Designs, Incorporated, 8400 Westpark Drive, P. O. Box 907, McLean, VA 22102	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS: Defense Advanced Research Projects Agency, 1400 Wilson Boulevard, Arlington, VA 22209	12. REPORT DATE: DECEMBER 1978
	13. NUMBER OF PAGES: 94
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): Office of Naval Research, 800 North Quincy Street, Arlington, VA 22217	15. SECURITY CLASS. (of this report): UNCLASSIFIED
	15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Decision Analysis
Resource Allocation
Program Objectives Memorandum
Cost-Benefit Analysis
Multi-Attribute Utility Analysis

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes several applications of decision analysis to the Army's Affordability Study. These applications are focused on the allocation of resources to support the requirements, concepts, plans and programs of the Army. Decision Analysis is a quantitative procedure for the systematic evaluation of the alternatives available to a decision maker. Decision-analytic techniques are used to structure a decision problem into clearly defined components, so that all options, outcomes, values, and —

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

(cont)

probabilities are depicted. The first application of decision analysis described in this report is the use of cost-benefit analysis to rank the Army Program Development Increment Packages (PDIP's) and Program Analysis Resource Review (PARR) issues. The cost-benefit process involves quantifying the relative benefits and costs of each program. Since the purpose of the prioritization is to determine the allocation of money to a discrete number of programs, the quantification of benefit is done according to an Army mission value system, not according to a monetary value system. Once the benefits have been quantified, the programs can be prioritized from the most cost-beneficial (benefit per dollar) to least cost-beneficial. This procedure has been applied to the prioritization of 334 PARR issues and 185 PDIP's in the POM FY 80-84 development.

Multi-attribute utility analysis is the second decision-analytic technique investigated during this affordability study. A multi-attribute utility model is hierarchical in nature, as the top-level factor in the analysis is successively divided at the bottom of the heirarchy. Multi-attribute utility analysis can be used in the relative evaluation of mission capabilities to develop a framework that sponsors could use to scale the benefits of their programs. It could also be used to develop a Support Packaging Methodology. These two methodologies would be most useful in establishing levels of functional programs to be ranked in the marginal analysis during the POM preparation.

End
4-79